Mineral Development Division
Department of Mines and Energy
Government of Newfoundland and Labrador

GEOLOGY OF THE GRANDYS LAKE AREA (110/15), NEWFOUNDLAND

Part I by Lesley Chorlton

Part II by Ian Knight

Report 83-7

St. John's, Newfoundland
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PART I: GEOLOGY OF THE SOUTHERN LONG RANGE MOUNTAINS

L. Chorlton

ABSTRACT

The Grandys Lake map area (110/15) is traversed by two major faults, the Long Range and Cape Ray Faults. Carboniferous sedimentary rocks are exposed northwest of the Long Range Fault, and deformed by the fault. The area between the Long Range and Cape Ray Faults is underlain by the metamorphosed, ophiolitic Long Range Mafic-Ultramafic Complex capped by metasedimentary rocks, and intruded by synkinematic/synmetamorphic tonalite and later granitoid plutons. Metasedimentary rocks and amphibolite intruded by synmetamorphic granitoid rocks are exposed southeast of the Cape Ray Fault. The northwest side of the Cape Ray Fault zone is unconformably overlain by the Early to Middle Devonian Windsor Point Group, composed of sedimentary and volcanic rocks deformed by late activity on the fault.

The geological development of the area can be envisaged in four major stages prior to the Carboniferous:

Stage one: In the northwest, Stage one involves the formation of ophiolite overlain by graywacke, marble, and pelagic sedimentary rocks. In the southeast, graywacke and shale with associated mafic volcanic and plutonic rocks also belong to Stage one, but deposition of some of the sedimentary and volcanic rocks may have overlapped in time with Stage two of the northwestern terrane.

Stage two: Intense regional deformation under high grade metamorphic conditions accompanied thrusting in the northwestern terrane. Crustally derived tonalitic magmas were emplaced and deformed while imbrication continued. Dioritic to quartz monzonitic plutons were emplaced after this deformation, but before post-metamorphic uplift.

In the southeast, thrusting preceded the amphibolite facies metamorphic peak and the generation and emplacement of synmetamorphic granitoid rocks.

Stage three: In the southeast, the third stage began as an episode of intense deformation under the ambient amphibolite facies metamorphic conditions and culminated with the Cape Ray Fault. Uplift of terrane along the northwest side of the Cape Ray Fault, probably associated with wrench faulting, was either accompanied or followed by the eruption of a bimodal volcanic suite and the deposition of sedimentary rocks of the Early to Middle Devonian Windsor Point Group along the fault.

Stage four: The deepseated rocks southeast of the Cape Ray Fault zone were uplifted obliquely against the Windsor Point Group through northwesterly-directed reverse faulting. This was accompanied and/or followed by the emplacement of leucogranite plutons, and mafic and felsic dikes.

Stages two to four correspond to three temporally distinct, major episodes of penetrative deformation in the terrane southeast of the Cape Ray Fault, i.e., Stage 2 = D_1; Stage 3 = D_2; Stage 4 = D_3. Northwest of the fault, the major penetrative deformation can be assigned to stage two; subsequent stages affected the terrane inhomogeneously.

The most obvious effects of Carboniferous deformation are in the uplift of an ophiolite-based belt along the Long Range Fault, and minor faulting and local chevron folding southeast of this belt.

The southern Long Range Mountains have potential for cupriferous massive sulfides, porphyry copper, and gold. Gold occurrences along the Cape Ray Fault have recently been investigated by Riocanex Ltd.. Metamorphism, shearing, and hydrothermal activity may be significant factors in siting metalliferous deposits in this area, and lake sediment geochemical anomalies in Pb, Zn, and Ag coincide with shear zones or lineaments.

1. INTRODUCTION

1.1 Location and access

The Grandys Lake area is situated in the southern Long Range Mountains of southwestern Newfoundland about 22 km northeast of Channel-Port-aux-Basques. Its boundaries coincide with latitudes 47° 45, and 48° 00, north and longitudes 58° 30 and 59° 00 west.

The Trans Canada Highway and the CNR railway follow the Codroy Valley in the northwest, but the southern Long Range Mountains southwest of the Long Range Fault are not accessible by road. Paths ascend the Long Range escarpment from South Branch in the Codroy Valley to the west, from logging roads north of the map area, and from the highway near Port aux Basques. All-terrain-vehicle tracks crisscross the western and northern ground, linking numerous hunting cabins. Since the brooks are not negotiable by boat and most ponds are too small or shallow to be used by float planes, helicopters are the best form of rapid access for most of the area.

1.2 Physiography

The Grandys Lake area occupies part of the physiographic subdivision of the Canadian Appalachians known as the Atlantic Upland (Twenhofel and MacClintock, 1940; King, 1972). The Long Range Fault diagonally crosses the northwest corner of the area and forms a well defined, northwest facing escarpment which separates the lowlying Codroy Valley from the southern Long Range Mountains. The mountains consist essentially of a glaciated highland plateau. Most topographic features of the highland are erosional, and are controlled mainly by rock type, structural grain, and by drainage. Minor glacial deposits, such as hummocky and drumlinoid moraines and a few eskers, contribute to the landscape.

The central and southern parts of the area are mostly barren, with a subarctic tundra vegetation. Spruce forest and mixed soft- and hardwood forest occupy stream valleys, and cover more extensive areas in the northwest near the well forested Codroy Valley.

1.3 Previous work

The regional geology of the Grandys Lake area was largely unknown until Gillis (1972) produced a 1:250,000 reconnaissance and compilation map and report of the Port aux Basques area (110) which includes the Grandys Lake (110/15) map sheet. He divided the rocks into two major sequences separated by the Long Range Fault (part of the Cabot fault system of Webb (1969)): (a) Carboniferous sedimentary rocks to the northwest of the fault, and (b) pre-Carboniferous metamorphic and crystalline rocks to the southeast. The Cape Ray Fault, which traverses diagonally across the Grandys Lake area, was also recognized as another major structural break, juxtaposing Ordovician (?) and possibly older rocks in the northwest against Ordovician (?) to Devonian rocks in the southeast. Several K/Ar age dates (Neale, 1963, 1965; Gillis, 1965, 1967, 1968) were cited in partial support of the latter age assignments.

The Carboniferous rocks exposed along the northwest side of the Long Range Fault have been subsequently mapped at 1:50,000 scale (Knight, 1975, 1976a, 1976b). The adjoining Codroy (110/14, southeast part; Brown, 1976c; Knight and Brown, 1977), Port aux Basques (110/11; Brown, 1977), Rose Blanche (110/10; Brown, 1976a), La Poile River (110/16; Chorlton, 1980b), and La Poile (110/9; Chorlton, 1978b) areas have also recently been mapped at 1:50,000 scale.

Several university theses on the geology of southwest Newfoundland have provided maps covering areas surrounding the Grandys Lake area:

(1) A Ph.D. study of the geology of the southwest end of the southern Long Range Mountains (Phair, 1949) was

accompanied by a 1:63,360 scale map of parts of the Port aux Basques (110/11) and Codroy (110/14) map areas. Phair described the area as underlain by an extensive pretectonic mafic to ultramafic stratiform igneous complex roofed by metasedimentary rocks, intruded by synorogenic to postorogenic granitic rocks.

(2) Brown (1972, 1975) outlined the structural and metamorphic history and basement-cover relations along the southwest coast east of the Long Range Fault, and produced 1:20,000 scale maps with several cross-sections. As a result of his studies, Brown (1973) made the pioneer attempt to define the role of southwest Newfoundland in the plate tectonic development of the Appalachian system, suggesting that the Cape Ray Fault was a cryptic suture along which two Precambrian continental margins from the opposite sides of the early Paleozoic proto-Atlantic Ocean were tectonically juxtaposed. Brown (1976b,c) subsequently identified the Long Range Mafic-Ultramafic Complex, the stratiform intrusion described earlier by Phair (1949), as segments of an ophiolite (oceanic crust belonging to the early Paleozoic proto-Atlantic ocean), and inferred that they had been obducted northwestward from the suture zone onto Grenvillian continental crust.

(3) The geophysical signature and geochemistry of several folded sheets of synkinematic granite in the Port aux Basques area were the subject of a thesis (Dingwell, 1980) accompanied by a 1:1,000 scale map.

Brooks (1970, 1972, 1974) studied the Quaternary geology of southwestern Newfoundland, emphasizing the region northwest of this map area. The glacial and surficial geology of the area has also been mentioned briefly in reports by Grant (1974) and Vanderveer (1977).

Much of the area was formerly included in a Brinex exploration concession granted in 1956, and until the mid 1970's mineral exploration activity in the area was relatively dormant. Taylor (1970) investigated the possible bedrock sources for stream sediment uranium anomalies in the eastern part of the area, originally targeted during a Brinex regional stream sediment geochemical survey. The project failed to reveal economic mineralization. In 1974, sulfide showings located by prospector George Bayly in the Cape Ray Fault zone near the source of Isles aux Morts Brook led to a gold discovery (Northern Miner, 1977, 1978, 1980). The origin, setting and geochemistry of the gold mineralization is presently the subject of a Ph.D. thesis by D.H.C. Wilton of Memorial University. The results of a lake sediment geochemical survey (Butler and Davenport, 1980) combined with the new gold discovery have stimulated economic interest in the region.

1.4 Present study

Part I of this report is concerned mainly with the pre-Carboniferous rocks which occupy the greater part of the Grandys Lake area and underlie the southern Long Range Mountains southeast of the Long Range Fault.

Mapping of the pre-Carboniferous terrane was accomplished by traversing radially from fly camps, and by spot checking by helicopter. The mapping party consisted of four persons: a project geologist, a senior mapping assistant, and two junior assistants. Field work occupied one month in 1979 and three months in 1980. Geological reconnaissance mapping of the Grandys Lake area (110/15) was the final stage of a 1:50,000 scale reconnaissance mapping project which covered the La Poile (110/9; Chorlton, 1978b), La Poile River (110/16; Chorlton, 1980b), and the west half of the Peter Snout (11P/13 W; Chorlton, 1980a) map areas. The author initiated the project as a Ph.D. thesis at Memorial University of Newfoundland (Chorlton, in preparation).

1.5 Lithostratigraphic nomenclature

Lithostratigraphic nomenclature used in this report (Table 1) differs from the usage of Gillis (1972), and Brown (1976a, 1976c, 1977). A discussion of the reorganization of map units is given in Appendix I.

1.6 General geology and regional setting

The Grandys Lake area is traversed by two major Devono-Carboniferous faults, the Long Range Fault and the Cape Ray Fault (Figure 1). The area northwest of the Long Range Fault is underlain by weakly deformed Carboniferous sedimentary rocks (Carboniferous block). The area between the Long Range and Cape Ray Faults (northwest block) is occupied by mafic and ultramafic plutonic rocks overlain by mafic volcanic rocks and sediments, all of which were polydeformed and metamorphosed while synkinematic, largely tonalitic granitoid magmas were emplaced, and were subsequently intruded by dioritic to granitic plutons. The mafic-ultramafic igneous rocks of the northwest block are referred to as the Long Range Mafic-Ultramafic Complex (Brown, 1976a). The area southeast of the Long Range Fault (southeast block) is occupied by metasedimentary, metavolcanic, and mafic meta-igneous rocks, also intruded by synkinematic tonalitic to granodioritic magmas during metamorphism after early deformation, and subsequently intruded by other granitoid plutons. The metasedimentary, metavolcanic, and mafic meta-igneous rocks are here referred to as 'Bay du Nord Group' (see Appendix I). The Cape Ray Fault became active after the emplacement and penetrative deformation of synkinematic granitoid rocks on either side. The Windsor Point Group, a bimodal volcanic and fluviatile assemblage of Early to Middle Devonian age, was deposited along the fault during or after its inception.

The northwest block is traversed by another, less significant fault which separates two ophiolite-based domains of slightly different nature. These domains are referred to here as the Little Codroy Pond belt and the Dinosaur Pond belt. The former includes the broad Stag Hill high strain zone, which merges with a high strain zone adjacent to the Long Range Fault. Another high strain zone affects the Dinosaur Pond belt in the north-central part of the map area, and is referred to here to as the north-central high strain zone (Figure 2).

The most convenient frame of reference for outlining the geological history of this area is provided by the effects of regional deformation and metamorphism, the activity of major faults, and the few dated rock units in the area. Therefore, these effects have here been used to separate the geological development into four stages prior to Carboniferous sedimentation and deformation; the Carboniferous fifth stage is the subject of Part II of this report. However, it is emphasized that tectonic events were not necessarily synchronous across the entire area (see Table 2). In addition, the northwest and southeast blocks may not have been contiguous before the deposition of the Windsor Point Group, since the lateral translation along the Cape Ray Fault is not known.

Stage 1

The first stage involved the generation of the oldest rocks in the area, the ophiolitic Long Range Mafic-Ultramafic Complex (Unit 1, parts of Units 3c-f) and the overlying sedimentary rocks (Units 2 and 3). The sedimentary rocks in the northwest block of graywacke and shale (Unit 2a: Little Codroy Pond belt), limestone (Unit 2b), and shale, graywacke, quartzitic sandstone, ferruginous claystone and chert, and possibly volcangenic rocks (Unit 2c: Dinosaur Pond belt).

Graywacke and shale (Units 3a,b) with minor interbedded mafic volcanic rocks (Unit 3e) in the southeast block, belonging to the 'Bay du Nord Group',

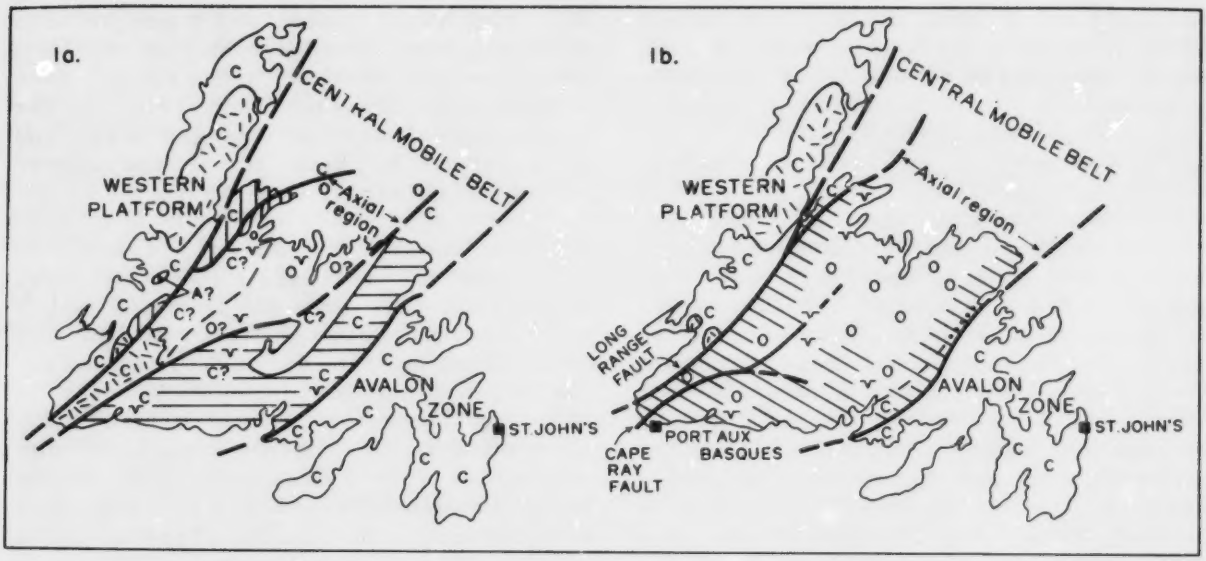


FIGURE 1A: *Map of Newfoundland showing the threefold subdivisions and the distribution of Eastern and Western crystalline belts and of immediately underlying continental and oceanic crusts as formerly envisaged (from Kennedy, 1976).*

FIGURE 1B: *Modification of the threefold subdivisions, and the distribution of Early Paleozoic continental and oceanic crust. Based on Williams (1979), Blackwood (1978), Colman-Sadd (1980), Chorlton (1980b), Hibbard (in preparation), and this study.*

EXPLANATION

Hadrynian-Cambrian

Western crystalline belt

Eastern crystalline belt

Helikian or older

Long Range Complex and equivalents

C *Early Paleozoic supracrustal rocks underlain by continental crust*

O *Early Paleozoic supracrustal rocks underlain by oceanic crust*

A? *Probably allochthonous*

EXPLANATION

Medium to high grade metamorphism of early Paleozoic rocks

o *Early Paleozoic supracrustal rocks underlain by oceanic crust*

C *Helikian or older crust (exposed)*

Grenvillian gneisses and anorthosite

V *Early Paleozoic volcanic rocks*

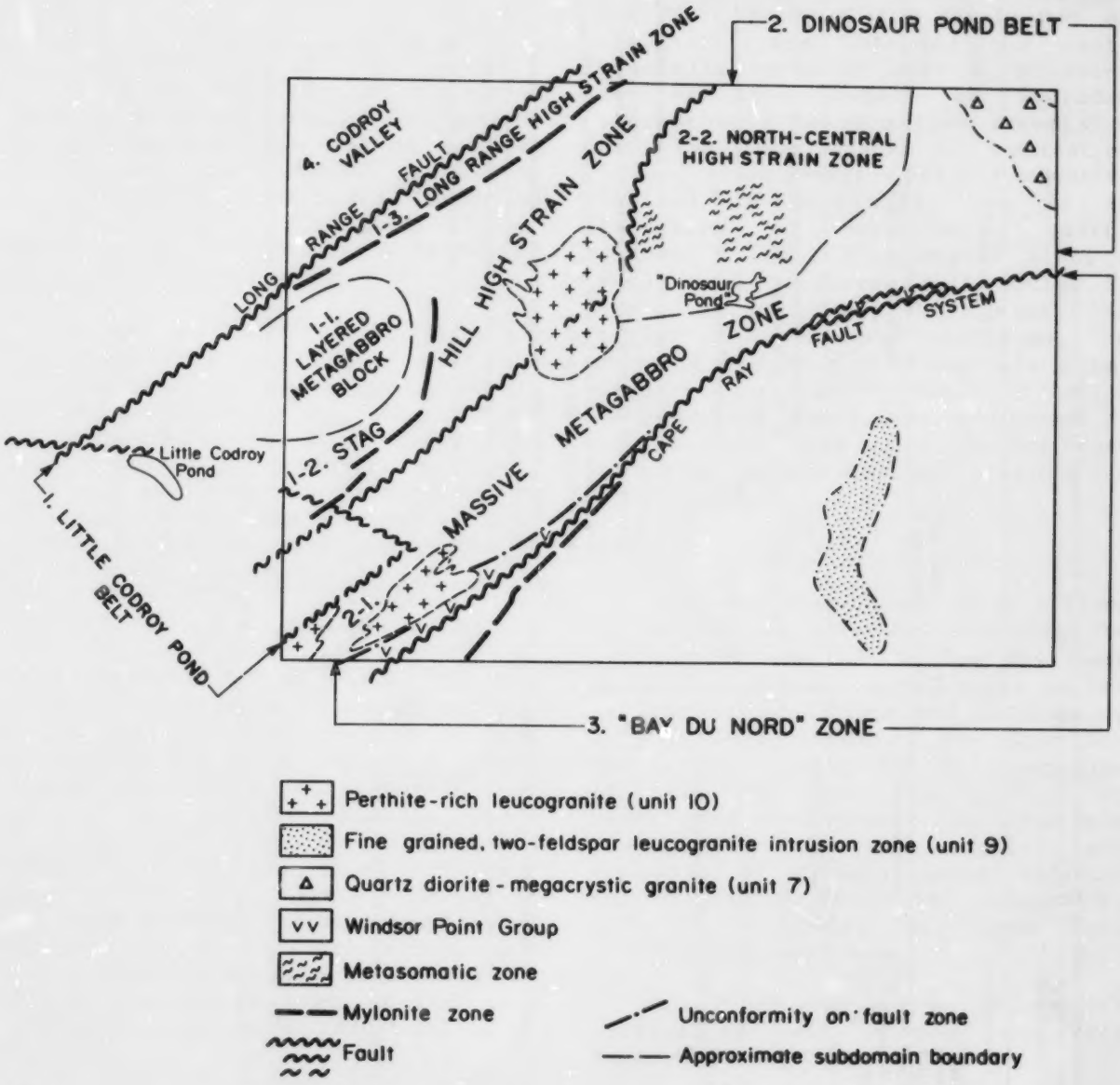


FIGURE 2: *Structural subdomains of the Grandys Lake area.*

TABLE 2: *Geological development of southwest Newfoundland, northwest to southeast, in Stages 1 through 4 and Carboniferous. Fault movements: (a) major ~~~~~~~~ ; (b) discontinuous; (c) minor - - - - - - . Emplacement of perthite-rich leucogranite plug* *Unconformity — · — · —*

Stage	NORTHWEST	LONG RANGE FAULT	CAPE RAY FAULT No. 1	CAPE RAY FAULT No. 2	SOUTHEAST	Stage
CARBONIFEROUS	CODROY GROUP	Uplift of Little Codroy Pond belt	minor deformation		minor faulting, chevron folding	CARBONIFEROUS
4	ANGUILLE GROUP		mafic and felsic dikes		uplift of polydeformed, amphibolite facies level of 'Bay du Nord Group' via reverse faulting	4
3	uplift of imbricated tonalite-ophiolite terrane		WINDSOR POINT GROUP (Emsian-Eifelian)		generation of two-feldspar leucogranite sinistral (?) deformation of 'Bay du Nord Group' under prevailing amphibolite facies metamorphic conditions	3
2B	emplacement of compositionally variable diorite, quartz diorite, *quartz gabbro, quartz monzonite and granite plutons		NO CONTACT ?		*La Poile batholith (U/Pb zircon 432 ± 20 Ma; probably not age of emplacement) metamorphism to amphibolite facies and partial melting to produce migmatite, and synmetamorphic tonalite to granite premetamorphic recumbent folding and thrusting in sedimentary and volcanic (forearc-arc) terrane	2
2	continued thrusting production of synkinematic tonalite and metamorphism ("dynamothermal") during thrusting initiation of thrust imbrication, possible formation of a "subduction complex" or "accretionary prism"				*Dolman tuff (U/Pb zircon 449 ± 20 Ma); Georges Brook tuff (446 ± 20 Ma) island arc volcanic and plutonic activity, and sedimentation in adjacent marine basin development of interarc sedimentary basins and beginning of arc magmatism	1
1	formation of oceanic crust				formation of oceanic crust	

*located outside Grandys Lake area

may have been deposited later than Unit 2, overlapping in time with Stage 2 of the northwest block.

Stage 2

The second stage involved the early, intense, polyphase regional deformation, the attainment of the peak of metamorphism, and synkinematic granitoid intrusion which accompanied (northwest block), or followed (southeast block), westerly or northwesterly directed imbrication and thrusting.

In the northwest block, thrusting was apparently synchronous with the attainment of the metamorphic peak in the high strain zones and the generation of synkinematic granitoid rocks. The lower parts of the ophiolitic crust may have initiated this deformation cycle at high temperatures, and presumably became partially hydrated where intersected by thrust zones. Consequently, they would have been either retrograded or partially melted depending on whether the temperature maintained was respectively lower or higher than the solidus temperature. Partial melting would explain the presence of the voluminous tonalite (Unit 4), and perhaps some of the later magmas that intruded the ophiolite and its cover. The lower parts of the ophiolitic crust, where thrust over high level rocks, may have transferred heat syntectonically to the rocks beneath. Repeated imbrication may have caused the superposition of a synkinematic metamorphic aureole within the north-central high strain zone underneath a now-eroded thrust sole.

In the southeast block, early recumbent folding and/or thrusting resulted in tectonic burial, and was followed by the attainment of the peak metamorphic conditions accompanied by local migmatization and emplacement of synmetamorphic granitoid sheets (Unit 5). The thickest sheets were probably generated slightly deeper in the metamorphic pile. After emplacement, the granitoid rocks were intensely deformed under the prevailing metamorphic conditions.

Stage 2b

Two intrusions northwest of the Cape Ray Fault preceded the development of the fault and intruded the early granitoid rocks of Unit 4. However, whether they should be included conceptually as magmatism associated with the later stages of imbrication (above) or as Devonian Stage 3 magmatism (below) is uncertain. One is an intrusion of megacrystic quartz monzonite (Unit 6), located along a shear zone boundary fault active in Carboniferous time, which makes its timing of emplacement ambiguous. The other is an intrusion of quartz diorite-megacrystic granite (Unit 7) which postdated the penetrative deformation of the tonalite (Unit 4) in the northeast corner of the map area, and predated the Cape Ray Fault.

Stage 3

The third stage began as an episode of deformation intensely affecting the terrane southeast of the Cape Ray Fault under the ambient amphibolite facies metamorphic conditions and culminating in the development of the Cape Ray Fault. Uplift along the northwest side of the Cape Ray Fault, probably associated with wrench faulting, was accompanied by the eruption and deposition of strongly bimodal volcanic and associated terrestial sedimentary rocks of the Windsor Point Group (Unit 8) along the fault zone.

Unit 9 and some of the leucogranite plutons of Unit 10 may have been emplaced during Stage 3.

Stage 4

During the fourth stage, the 'Bay du Nord Group' and the synkinematic granitoid rocks (Unit 5) were uplifted obliquely against the Windsor Point Group in the Cape Ray Fault zone, and elsewhere against the tonalite/ophiolite terrane north of the fault, by combined northwesterly directed reverse and

oblique-slip faulting. This was followed by, or may have accompanied, the emplacement of late leucogranite plutons (Unit 10) and mafic and felsic dikes (Unit 11). Alternatively, some of the plutons of Unit 10 may have been emplaced during Stage 3.

Stage 5 (Carboniferous)

The Carboniferous sedimentary rocks northwest of the Long Range Fault belong to the Anguille Group (Tournaisian?), the Codroy Group (Middle to Upper Viséan), and the Barachois Group (Westphalian A) (Baird and Cote, 1964). The Codroy and Barachois Groups were deposited after emplacment of the youngest plutonic rocks in the terrane southeast of the Long Range Fault, but it is possible that the Anguille Group was deposited before the cessation of plutonism and stage three tectonic activity. Carboniferous or younger deformation locally affected all units. Uplift of a strip of the pre-Carboniferous ophiolitic terrane along the present Long Range Fault affected the adjacent Carboniferous rocks. This activity may have been accompanied by dextral strike-slip movement (Knight, 1983) and block faulting on smaller, reactivated faults and shear zones in the pre-Carboniferous terrane.

Previously suggested tectonic model for southwest Newfoundland

Tectonic models for the Newfoundland Appalachians involve the opening of a proto-Atlantic ocean in Cambrian to earliest Ordovician times, and the subsequent closing of this oceanic tract (Wilson, 1966). In closing, east to southeast dipping subduction which produced an island arc terrane in central Newfoundland, evolved into west or northwest directed thrusting which finally resulted in the obduction of oceanic crust following collision of arc terrane with the western continental margin.

In southwest Newfoundland, the oceanic and island arc tract has previously been considered completely obliterated by the collision (Williams, Kennedy, and Neale, 1970). The Cape Ray Fault was subsequently interpreted as the cryptic suture which juxtaposed the two Precambrian continental basement complexes, the 'Long Range Gneiss' and the 'Port aux Basques Gneiss' (Brown, 1973), the former belonging to the western continental margin and the latter to the eastern margin of the proto-Atlantic ocean. Furthermore, Brown (1976b) suggested that exposures of the ophiolitic Long Range Mafic-Ultramafic Complex northwest of the Cape Ray Fault were remnants of the pinched out oceanic tract, obducted onto the 'Long Range Gneiss.' The rooted portion of the axial region of the Central Mobile Belt (Williams, 1964), the zone characterized by Early Paleozoic oceanic crust overlain by island arc and marine sedimentary sequences, was thought to be pinched out along the Cape Ray Fault to the northeast of the project area (Kennedy, 1976; Brown and Colman-Sadd, 1976).

Recent work in the La Poile (110/9) and La Poile River (110/16) areas challenges this interpretation, and has revealed that the area southeast of the Cape Ray Fault is underlain by an Ordovician metavolcanic pile with island arc affinities grading laterally into a probable marine metasedimentary sequence and associated amphibolite (Chorlton, 1980b). These rocks are presently assigned to the Bay du Nord Group (Cooper, 1954, modified by Chorlton, 1980b), and the time equivalent La Poile Group (Cooper 1954, modified by Chorlton, 1978). The metasedimentary rocks and associated amphibolite continue into the Grandys Lake area, and can be correlated with the 'Port aux Basques Gneiss' of Brown (1975) (Appendix I), previously considered Precambrian continental basement. Mafic plutonic rocks interpreted to form the basement of the exposed metavolcanic pile south of the Cape Ray Fault

(Chorlton, 1980a,b) are composed partly of ophiolitic high level gabbros representing segments of Lower Paleozoic oceanic crust and partly of mafic to intermediate intrusive rocks probably related to the overlying volcanic sequences (G.R. Dunning, personal communication, 1981). Northwest of the Cape Ray Fault in the Grandys Lake area, field relations indicate that lower Paleozoic ophiolitic rocks of the Long Range Mafic-Ultramafic Complex (Brown, 1976b) are also the oldest rocks exposed (Appendix I). Therefore, the Cape Ray Fault can no longer be considered a cryptic suture between two continental basement terranes. Geology typical of the axial portion of the Central Mobile Belt, although more highly deformed and metamorphosed, is actually exposed on both sides of the fault.

Newly proposed tectonic model incorporating field data and age constraints

The geological development of the Grandys Lake and surrounding areas reflects the evolution of the proto-Atlantic Ocean from the earliest stages of closure to cratonization of the oceanic terrane (and inferred collision of the arc-trench gap with the early Paleozoic North American continent). Oceanic crust rapidly attained a continental character by means of subduction-related island arc volcanism and plutonism which evolved during collision into syntectonic granitoid emplacement. This was followed by wrench faulting, the deposition of Devonian fault-controlled sedimentary assemblages and associated bimodal volcanic rocks, and late stage granite emplacement.

Subduction resulted in the development of the central Newfoundland island arc system. Rocks belonging to one of the volcanic centres are exposed southeast of the area near La Poile Bay. An 'outer arc' rise in the northwest may have resulted in the formation of a forearc sedimentary basin in front of the volcanic arc. In the northwest part of the area, early imbrication of oceanic crust and its sedimentary cover, either within the upper oceanic plate or in an 'accretionary wedge', may have been accompanied by the generation of synmetamorphic/synkinematic tonalite within the thrust complex, perhaps while the latest stages of sedimentation and island arc volcanic and plutonic activity continued in the southeast. In addition, megacrystic quartz monzonite and a diorite/granite body was emplaced in the northwestern terrane after deepseated deformation of the tonalite, before postmetamorphic uplift.

Upon final collision with the North American continental margin, ophiolite imbrication continued in the northwest, and premetamorphic recumbent folding and possibly thrusting affected the island arc terrane to the southeast. This caused tectonic burial and subsequent medium to high grade regional metamorphism, accompanied by the generation of synkinematic granodiorite and tonalite in the forearc and arc areas. Further deformation under amphibolite facies conditions in this terrane apparently reflects the beginning of a compressive simple shear system (transpression; Harland, 1971) which culminated with the development of the Cape Ray Fault.

The eruption and deposition of bimodal volcanic and sedimentary rocks of the Devonian Windsor Point Group occurred along an 'intracratonic' wrench basin controlled by the early Cape Ray Fault. Deposition was halted by oblique, high angle thrusting of the older, deformed rocks in the southeast against the Windsor Point Group, and continued strike-slip movement. Potassic granite plugs and mafic and felsic dike swarms signify the latest magmatic activity.

The Carboniferous sedimentary basin largely postdated the development of the terrane southeast of the Long Range Fault. However, the initial development of the Anguille Group basin may have coincided with movement on the Cape Ray Fault system (Knight, 1983). The

Carboniferous rocks were affected by late uplift along the Long Range Fault, and by continued stress resolved by minor folding and faulting.

1.7 Petrographic techniques and granitoid terminology

Approximate mineral compositions of plagioclase, olivine, and orthopyroxene were determined optically without the benefit of a universal stage. The anorthite content of plagioclase was determined using the bisectrix method of Winchell (1949), and is reported as a single value, a range of values, or as the plagioclase species (e.g. oligoclase) encompassing the compositional range encountered. Where possible, the forsterite content of olivine and the enstatite content of orthopyroxene were estimated using published curves (Heinrich, 1965). Many thin sections did not yield grains of suitable orientation for these methods.

Hornblendes are designated as blue-green, green, brown-green, or igneous brown according to their pleochroism:

blue-green: Z = blue-green
Y = forest or grass green
X = straw yellow

green: Z = green, dark green
Y = green, olive green
X = straw yellow

brown-green: Z = gray-tan or olive green
Y = tan-brown
X = pale tan to colorless

igneous brown: Deep pinkish brown with high dispersion which masks pleochroism.

All of the above hornblendes are biaxial negative with moderate to large $2V_x$. Fibrous blue-green amphibole, probably actinolite, displays the same pleochroic scheme as the blue-green hornblende. blue-green amphiboles which may be either hastingsite or hornblende, and amphiboles with pleochroic schemes other than those listed above, are specified in the text. The brown green hornblende has a $2V_x$ of 80-85°, and maximum interference colors in the lower second order.

Modal rock compositions were estimated visually. The nomenclature of Streckeisen (1973) was used for naming the granitoid rocks with the exception of plagiogranite. The term plagiogranite is applied here to granitoid rock made up largely of plagioclase and quartz with minor clinopyroxene or hornblende, and refers specifically to small injections or pods which intrude high level gabbros and diabase of the Long Range Mafic-Ultramafic Complex. The plagiogranite is considered part of the complex. In addition, tonalitic rocks with more than 25 modal per cent ferromagnesian minerals are referred to here as quartz diorite, and the term tonalite is restricted to less mafic rocks.

The textural terms granophyre and myrmekite follow conventional usage summarized by Barker (1970).

The nomenclature of Sibson (1977) is applied to fault rocks, mainly of the mylonitic class.

General metamorphic grade was determined from easily recognizable mineral indicators (cf. Miyashiro, 1973), although their use involves a degree of imprecision.

2. ROCKS THAT PREDATE THE EARLY REGIONAL DEFORMATION AND METAMORPHISM, AND BELONG TO STAGE 1

2.1 Introduction

These rocks are represented north of the Cape Ray Fault by the Long Range Mafic-Ultramafic Complex (1) and subordinate metasedimentary rocks (2), and south of the fault by metasedimentary rocks and amphibolite of the modified Bay du Nord Group (3). The Long Range Mafic-Ultramafic Complex is interpreted as Early Paleozoic oceanic (ophiolitic) crust (Brown, 1976b). Figure 3a shows the distribution of these units in the Grandys Lake and neighbouring map areas, Figure 3b an interpretive cross-section.

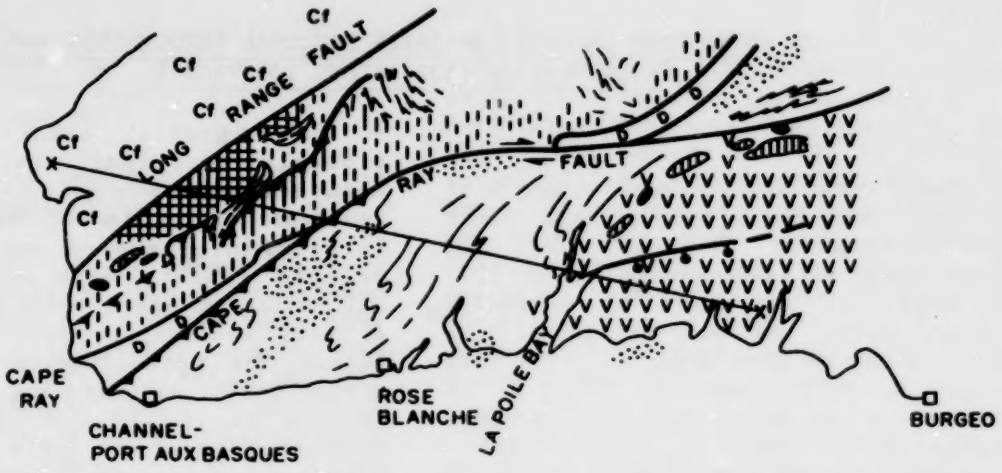
No correlation between the metasedimentary rocks on either side of the Cape Ray Fault can be made. However, local thickly layered, coarse grained amphibolites (Unit 3d) southeast of the Cape Ray Fault resemble highly deformed and metamorphically recrystallized, layered metagabbros of the Long Range Mafic-Ultramafic Complex. In addition, fragments of a metagabbro and metadiabase complex resembling the upper portions of the Long Range Mafic-Ultramafic Complex are intruded by pretectonic, fine grained quartz metagabbro or metadiorite, and are interpreted from field relations as the basement to the Bay du Nord volcanosedimentary terrane around the Blue Hills of Couteau in the La Poile River (110/16) and Peter Snout (11P/13) areas. Therefore, fragmented ophiolitic metagabbros may be at least one constituent of the basement underlying the 'Bay du Nord' metasedimentary and metavolcanic terrane, and some of the more coarse grained, massive amphibolite wedges exposed in the Grandys Lake and neighbouring map areas may be similar in protolith to the Blue Hills of Couteau complex.

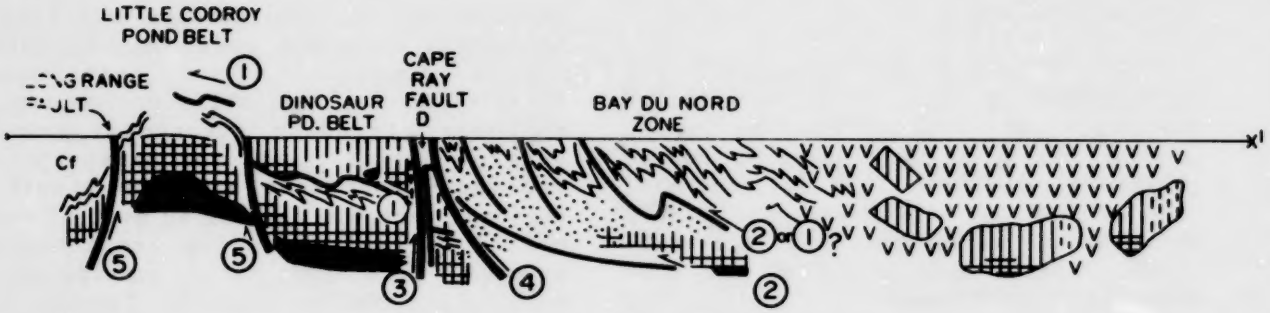
The pretectonic assemblages contrast from northwest to southeast across the Cape Ray Fault in two main features:

(1) A greater areal extent, and probably original thickness, of metasedimentary rock is exposed southeast of the fault. These rocks are largely interlayered semipelitic and pelitic schists with minor marl or calc-silicate bands which may represent a thick sedimentary pile of a marine basin. The metasedimentary rocks pass gradationally eastward and southeastward into a marine to locally subaerial volcanosedimentary pile related to island arc volcanism (Chorlton, 1980b).

(2) Southeast of the fault, early penetrative, regional fabrics were later intensely deformed under amphibolite facies conditions, and transposed parallel to the regionally predominant, northeast trending structural grain before uplift and postmetamorphic cooling. Northwest of the fault, regional tectonic fabrics in most of the mafic-ultramafic complex are inhomogeneously developed; early, penetrative, amphibolite facies tectonic fabrics in rocks highly reconstituted by deformation, such as paragneiss and undivided amphibolite, were uplifted to higher tectonic levels and cooled postmetamorphically before they underwent late stage deformation. Therefore, early northwest trending fabrics are only locally transposed by the late northeast trending structures.

These two factors might explain: (1) the gradual change from positive to negative gravity anomalies from northwest to southeast (Weaver, 1967; Miller, 1977), and (2) the change in aeromagnetic pattern (Geological Survey of Canada, 1971) which slightly overlaps the Cape Ray Fault system. The gravity contrast may also reflect an increasing proportion of syntectonic granitoid rocks (Rose Blanche and Port aux Basques phases (see Appendix I), and the La Poile batholith (Cooper, 1954)) as well as the thick volcanic and subvolcanic island arc assemblage in the southeast.





EXPLANATION

Carboniferous sedimentary rocks . . . . . Cf

Devonian volcanic and sedimentary rocks. . . . . . D D D

Ordovician metasedimentary rocks, structural trends indicated. . . . . .

Ordovician island arc metavolcanic, subvolcanic, and volcaniclastic rocks . . . . . V V V V V V V V V V

Fault, movement and relative stage indicated . . . . .

Thrust fault (may have sited later movement). . . . . .

OPHIOLITIC ROCKS

High level gabbro, diabase, basalt . . . . .

High level gabbro, diabase, basalt, engulfed by tonalite . . . . .

Layered, cumulate Ol-bearing metagabbro . . . . .

Massive ultramafic rocks . . . . .

Amphibolite of probably partly ophiolitic, partly subvolcanic to volcanic origin . . . . .

FIGURE 3: *Approximate distribution of ophiolitic rocks and derivative amphibolite, and Ordovician metasedimentary and island arc metavolcanic, subvolcanic, and volcaniclastic rocks in southwest Newfoundland.*

2.2 Long Range Mafic-Ultramafic Complex (Unit 1)

Definition

The Long Range Mafic-Ultramafic Complex was originally defined by Brown (1976b, 1977) as a series of layered gabbros together with overlying massive gabbro and underlying altered ultramafic rocks which occurs as thrust sheets in the Codroy and Port aux Basques areas (Brown, 1976b, 1976c). The name Long Range Mafic-Ultramafic Complex is applied here to all of the mafic and ultramafic meta-igneous rocks which predate the intrusion of tonalite (4), and which are believed to be parts of the sequence from ultramafic rock (1a) to layered metagabbro (1b) to massive metagabbro and metadiabase (1c) described by Brown (1976b) (see Appendix I). The complex also includes mafic metavolcanic rocks and dikes (1d) and undivided amphibolite (1e).

The ultramafic rocks occur as lenses within the layered metagabbro, as pods surrounded by tonalite which also engulfs the massive metagabbro and metadiabase, and as pods or lenses in contact with undivided amphibolite in the Stag Hill high strain zone. Layered metagabbro grades into the massive metagabbro and metadiabase, which is in turn adjacent to the mafic metavolcanic rocks and dikes. The layered metagabbro underwent early deformation under granulite facies conditions. All subunits have been subjected to regional metamorphism, but due to their competent nature and inaccessibility to metamorphic fluids some of the rocks retain their early texture and mineralogy. All grade into undivided amphibolite locally.

Ultramafic rocks (Unit 1a)

The term ultramafic rock refers to rocks which contain over 90 per cent ferromagnesian minerals on an outcrop scale, but which contain gradational lenses of rock with over 10 per cent plagioclase. Ultramafic rocks form sharply bounded, discontinuous bands or boudinaged lenses of partly altered feldspathic peridotite within the layered metagabbro sequence, and more highly altered dunite and peridotite within amphibolites of the Little Codroy Pond belt. Isolated metadunite pods up to 30 m in diameter occur within the tonalite intrusion and mafic inclusion complex of the Dinosaur Pond belt.

Feldspathic peridotite within the layered sequence is composed of olivine, plagioclase, clinopyroxene, hornblende, rare orthopyroxene, and minor opaques with accessory brown phlogopite and olive green spinel. Secondary serpentine and fine grained magnetite is abundant. Olivine (Fo_{90}-Fo_{65}) is the predominant mineral in all ultramafic phases, and forms anhedral, ovoid domains 1 to 7 mm in diameter which contain a network of serpentine and fine grained magnetite wisps (Plate 1). Plagioclase (labradorite in several specimens) occurs mainly as lens shaped clusters or interconnecting stringers of anhedral grains. Clinopyroxene commonly occurs as large, pale brown poikilitic grains of diallage which enclose olivine and plagioclase. Orthopyroxene is pleochroic in pale shades of pink and green, and occurs as small grains around clinopyroxene or plagioclase. Pinkish brown, igneous hornblende with high dispersion occurs as rims around cuspate opaque oxide grains, and as single anhedral crystals. Coronas of tremolite/actinolite between olivine and plagioclase are common, and double coronas on olivine with tremolite inside and actinolite outside were observed locally.

Altered harzburgite near Long Pond in the Stag Hill high strain zone is completely surrounded by outcrops of migmatitic metasedimentary rock and garnetiferous granite. The harzburgite consists of an aggregate of large and very small domains of optically continuous olivine in a network of serpentine and fine grained magnetite, accompanied by ragged, bent, and twinned

Plate 1: *Photomicrograph of feldspathic peridotite (1a) from the layered metagabbro sequence, showing folded stringer of polygonized plagioclase (pg) and partly serpentinized olivine (ov). DD-80-358. Plane polarized light.*

crystals and crystal aggregates of clear orthopyroxene (bastite). Some orthopyroxene crystals enclose tiny, anhedral olivine grains. Secondary calcite patches and a few isometric opaque grains are accessory constituents. Bastitized enstatolite veins the outcrop.

Other ultramafic rocks within the Stag Hill high strain zone consist largely of serpentine net-veined with fine, wispy magnetite, but alteration assemblages locally include talc, chlorite, and tremolite. Poikilitic uralitized clinopyroxene and relict olivine were observed in a strongly sheared, serpentinized wehrlite pod in the northeast. Minor concentrations of disseminated, purplish black, submetallic chromite were observed in the ultramafic pods surrounded by amphibolite in the northern part; however, magnetite is the more common macroscopic spinel. Patches of finely matted to granular rodingite accompany some serpentinized masses. Thick veins of serpentine were noted locally.

Ultramafic pods in the Dinosaur Pond belt are composed mainly of olivine net-veined by serpentine and wispy magnetite, and overprinted by patches of secondary calcite. Olivine (Fo_{90} approximately) occurs as remnants in the serpentine matrix.

Layered metagabbro (Unit 1b)

Well defined layering, mineral lamination, and high olivine content distinguish Unit 1b from the massive metagabbro and metadiabase of Unit 1c. Massive metagabbro and metadiabase is in gradational contact with the layered metagabbro.

The most obvious macroscopic layering mainly reflects fluctuations in plagioclase content, and occurs on a scale of 1 to over 100 cm (Plate 2). Cumulate olivine metagabbro, meta-troctolite, meta-anorthosite, and anorthositic metagabbro, form most of the layers in the main part of the sequence. Graded bedding is locally visible in troctolite bands. Coarse,

subophitic clinopyroxene metagabbro interbands, with clinopyroxene augen up to 5 cm in diameter, occur at the transition into the massive metagabbro and metadiabase.

The layered metagabbro possesses an early granulite facies S-L fabric nearly parallel to layering (Plates 2, 3). Amphibolite facies and lower grade minerals are superimposed locally. A rare, gabbronorite outcrop (below) lacks this foliation.

The granulite facies, layered metagabbros contain plagioclase, olivine, clinopyroxene, subordinate orthopyroxene, and minor brown hornblende (Plate 4). Opaque minerals, emerald green spinel, and rare biotite are accessory minerals. Granoblastic plagioclase ranges in composition between An_{50} and An_{70}, but grains as sodic as An_{65} were found. Olivine (Fo_{90} and Fo_{65}) forms lozenge-shaped grains, aggregates and polygonized lenses which partly define the foliation and banding. Beige clinopyroxene grains are polygonized and subophitic, with boundary subgrains. They display thin exsolution lamellae. Diallage partings are decorated with fine opaques. Orthopyroxene grains with pale pink-green pleochroism cluster around olivine or clinopyroxene and are commonly polygonized. Anhedral, pinkish brown hornblende is ubiquitous,

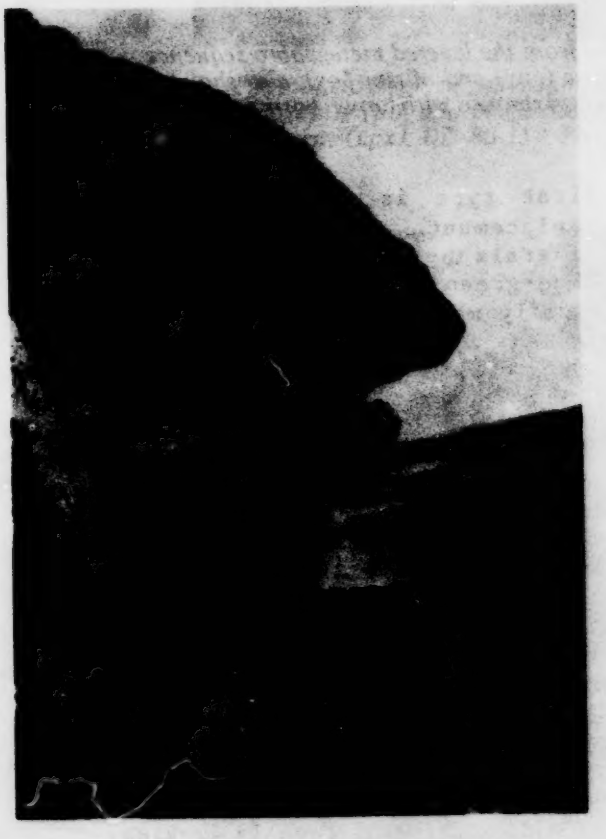


Plate 2: *Layered metagabbro (1b) showing anorthosite bands parallel to foliation.*

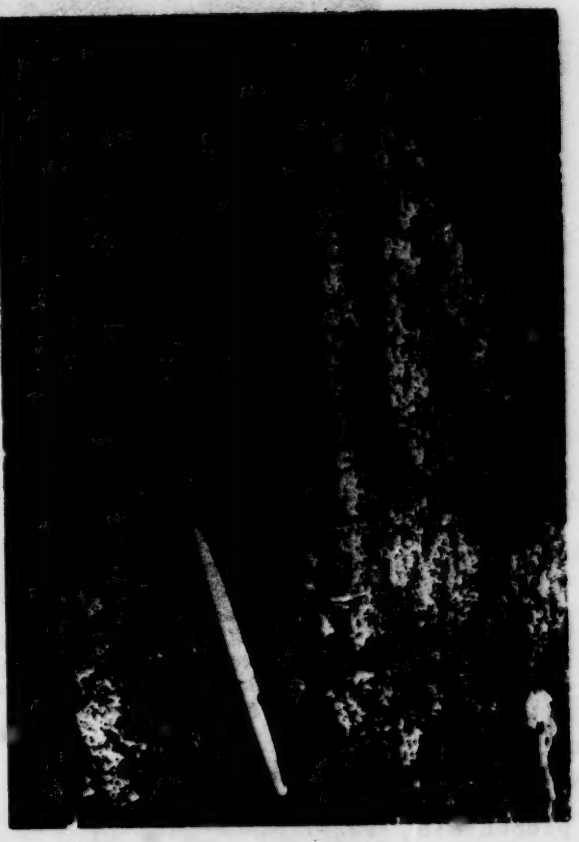


Plate 3: *Layered metagabbro (1b) showing either truncated bedding or the attenuated nose of a tight fold. Note pronounced foliation.*

Plate 4: *Photomicrograph of olivine metagabbro from the layered metagabbro sequence (1b), showing polygonized clinopyroxene (cpx) and olivine (ov); also showing grains of magnetite (mag) and Mg-spinel (sp) rimmed with brown hornblende (h). 80-LC-17. Plane polarized light.*

though not abundant; it surrounds cuspate magnetite grains. Deeply pleochroic, red-brown phlogopite or biotite is less abundant than hornblende, and locally occurs as rims of mica-quartz symplectite. Magnetite is the predominant opaque phase in all of the layered metagabbros. Fine grained magnetite and emerald green spinel generally occur together, and are relatively abundant in some rocks. Thin secondary tremolite coronas surround olivine grains in a few sections. Symplectite rims and lobes of pale blue-green, fibrous actinolite are also common locally.

The unfoliated gabbronorite is characterized by orthopyroxene, plagioclase, and phlogopite as cumulus phases, enclosed in partly uralitized, intercumulus clinopyroxene (Plate 5). Orthopyroxene occurs as subhedral, nonpleochroic grains with exsolution lamellae.

Retrogressed or regionally metamorphosed, layered metagabbros within the block are of two main varieties. The first type is characterized by the replacement of the ferromagnesian minerals by recrystallized lenses of blue-green hornblende (Plate 6), or locally mottled brown-green hornblende, and by accessory epidote, sphene, and rare rutile rimmed by sphene. (Where the hornblende is brown-green, the rocks lack sphene.) Granoblastic plagioclase (calcic andesine to labradorite) is preserved. The second type is characterized by replacement of the ferromagnesian minerals by fibrous blue-green amphibole and clinochlore (Plate 7), although brown igneous hornblende is preserved locally. Some of the rocks display remnants of clinopyroxene replaced by pale amphibole which is rimmed with more deeply pleochroic, blue-green amphibole (Plate 8). Epidote occurs as prismatic euhedra and as vermicular coronas on altered clinopyroxene grains; sphene is lacking.

Biotite-plagioclase-quartz pegmatites and fewer gabbroic pegmatites intrude the layered sequence. Several

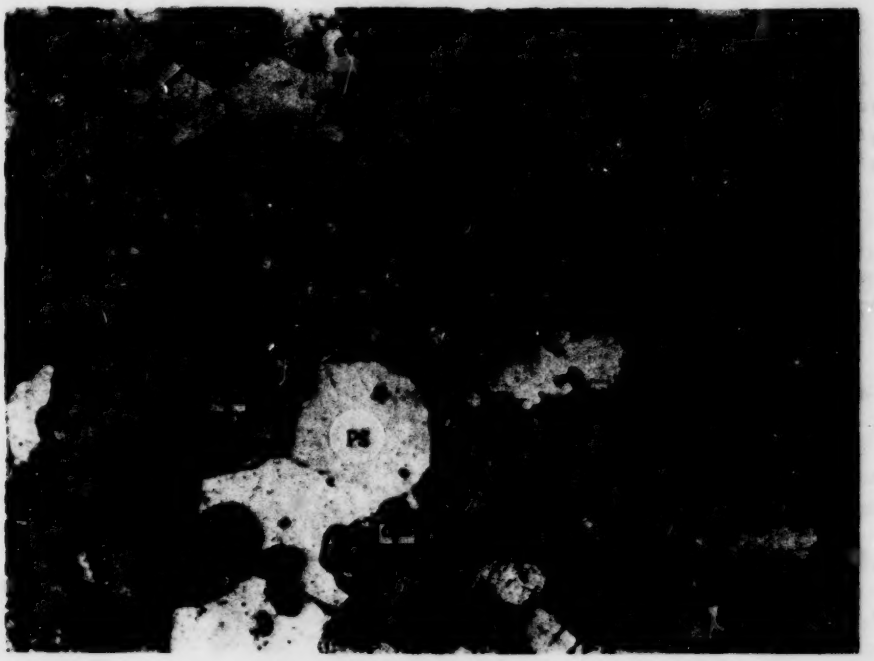


Plate 5: *Photomicrograph of gabbronorite with cumulus grains of orthopyroxene (opx), phlogopite (pl), and plagioclase (pg) ophitically enclosed in intercumulus clinopyroxene (cpx). DD-80-359. Plane polarized light.*

Plate 6: *Photomicrograph showing the effect of 'type 1' amphibolite facies retrogression: polygonized blue-green hornblende (h) has replaced poikilitic clinopyroxene. DD-80-343. Plane polarized light.*

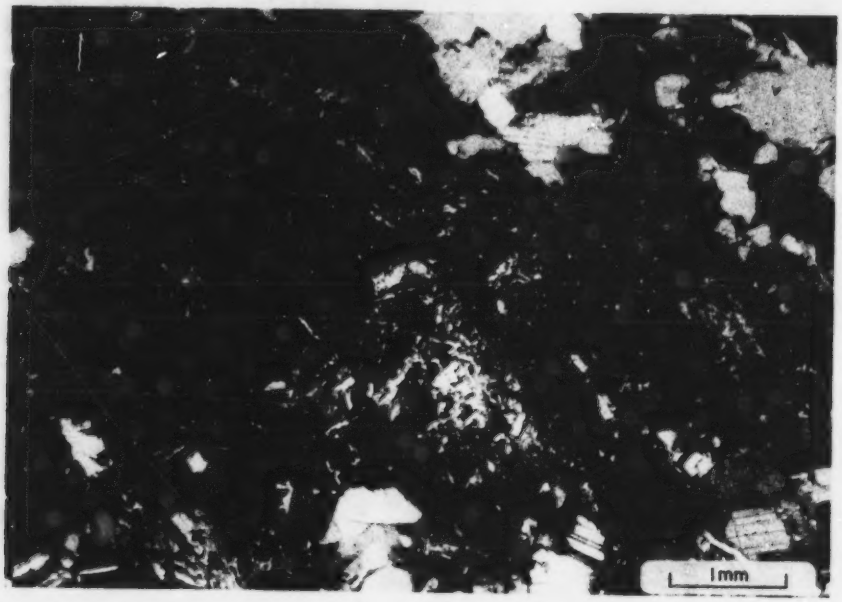


Plate 7: *Photomicrograph illustrating typical 'type 2' greenschist facies retrogression: ferromagnesian silicate minerals are replaced by fibrous actinolite and chlorite. DD-80-357. Cross polarized light.*

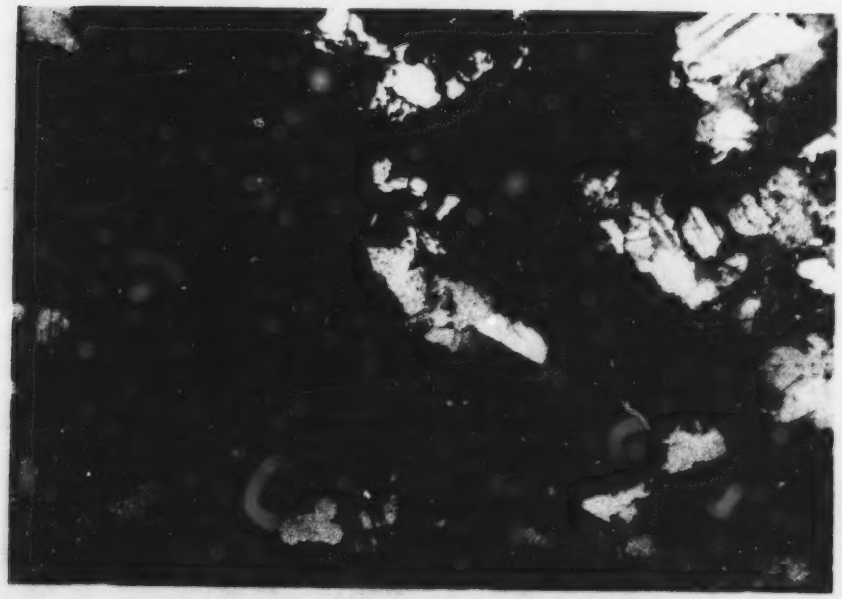


Plate 8: *Photomicrograph showing 'type 2' greenschist facies retrogression: poikilitic clinopyroxene is uralitizeds in patches. DD-80-357. Cross polarized light.*

fine grained plagioclase porphyry dikes (11b?) and one tuffisite dike also locally cut the sequence.

Massive metagabbro and metadiabase (Unit 1c)

Unit 1c is distinguished from layered metagabbro (1b) by the lack of well developed layering, the coarse to medium grained subophitic texture and the abundance of metadiabase intrusions. It is typically cut by plagiogranite stringers and pods, not present in layered metagabbro. Altered clinopyroxene is the major ferromagnesian mineral phase, and olivine is absent. The unit occurs both sparingly intruded by equigranular tonalite, and as 30 to 70 per cent mafic rock intruded by or enclosed in tonalite. The latter tonalite grades into garnetiferous tonalite enclosing mafic metavolcanic rocks and dikes, undivided amphibolite, and assorted metasedimentary rocks. In addition, the massive metagabbro and metadiabase grades into the layered metagabbros on both sides of the Little Codroy Pond belt.

Several rock types characterize this unit. The most common phase is clinopyroxene metagabbro which varies from coarse to medium grained in texture, and from plagioclase- to ferromagnesian-rich in composition. The clinopyroxene metagabbro is composed of altered clinopyroxene, plagioclase, brown igneous hornblende, and accessory magnetite and pyrite. Pale brown clinopyroxene, which makes up between 30 and 70 per cent of the rock, subophitically encloses plagioclase. It is altered to blue-green amphibole; many pseudomorphs have pale green cores and thin, more intensely pleochroic rims. Planar arrays of very fine opaque grains mark remnant diallage partings. Plagioclase occurs as subhedral laths, from andesine to bytownite, partly to totally replaced by clinozoisite and zoisite. Pale brown hornblende locally forms large, subophitic grains in conjunction with clinopyroxene. Magnetite forms both separate disseminated grains, commonly oxidized around the rim, and cuspate, brown igneous hornblende-rimmed grains. Rare secondary rutile is associated with opaque minerals. The clinopyroxene metagabbro is locally cut by very coarse grained hornblende metagabbro dikes, some of which display comb layering (Moore and Lockwood, 1973).

The metadiabase forms abundant irregular intrusions, and varies in texture from a granoblastic intergrowth of prismatic blue-green amphibole and altered plagioclase to recrystallized plagioclase (An_{70}) pheoncrysts in a fine grained matrix of blue-green hornblende and plagioclase. Secondary minerals are epidote or clinozoisite (after plagioclase) and coarse zoisite and muscovite (after plagioclase phenocrysts). There is accessory apatite and magnetite.

All of the rocks are intruded by plagiogranite pods and stringers, and in places by pegmatites of quartz, plagioclase, biotite and hornblende. Plagiogranite veins are white in color and sugary in texture, and present a startling contrast with the mafic plutonic rocks (Plate 9). The plagiogranite veins are composed of about 60 per cent labradorite, 20 per cent interstitial quartz, and 20 per cent anhedral uralitized clinopyroxene, with accessory brown zircon and secondary minerals including chlorite, epidote and sphene. The rock is generally fractured. Epidote and sphene are concentrated along the fractures.

Mafic metavolcanic rocks and dikes (Unit 1d)

Mafic metavolcanic rocks and dikes preserved in the Long Range high strain zone comprise massive metabasalts which either are cut by or occur as screens in equally metamorphosed mafic dikes. Thin, partly granitized pillow selvages, pillow junctions and margins

Plate 9: *Plagiogranite (white) cutting medium grained metagabbro (dark) in Unit 1c.*

with abundant flattened vesicles were observed locally. Dikes are inseparable from mafic metavolcanics in most places. Plagioclase-phyric and aphyric metabasalts are composed mainly of blue-green hornblende and plagioclase with accessory epidote minerals, sphene or leucoxene, and magnetite. Relicts of pale green pyroxene are present locally. Secondary actinolite and chlorite are associated with hornblende in some places. The ferromagnesian minerals of the metavolcanic rocks and dikes have been metamorphically recrystallized into fine, acicular amphibole which defines a pronouced foliation. Plagioclase phenocrysts display oscillatory zoning. They are almost completely replaced by coarse intergrowths of prismatic zoisite, which is also abundant in the matrix (Plate 10).

In the north-central high strain zone, fine grained amphibolitic metavolcanic rocks, diabasic textures, and plagioclase phenocrysts are preserved locally (Plate 11). Pillow-like structures with 2 to 4 cm thick weathered-out rims, epidosite lenses or pods, mafic breccias (Plate 12) and patches of green to buff, color banded, tuffaceous metasediment characterize the two largest outcrop areas. As with Unit 1c, exposures with almost no intrusive tonalite pass abruptly into those containing a large proportion of tonalite.

The rocks are composed of blue-green hornblende (60 to 70 per cent) and plagioclase with minor quartz and magnetite. There are relicts of pale green pyroxene. Traces of cummingtonite locally form an incipient alteration of hornblende. Secondary clinozoisite or epidote replaces plagioclase grains of some samples.

Undivided amphibolite (Unit 1e)

Deformed and metamorphically recrystallized mafic meta-igneous rocks for which a protolith is not recognizable in outcrop or hand specimen were

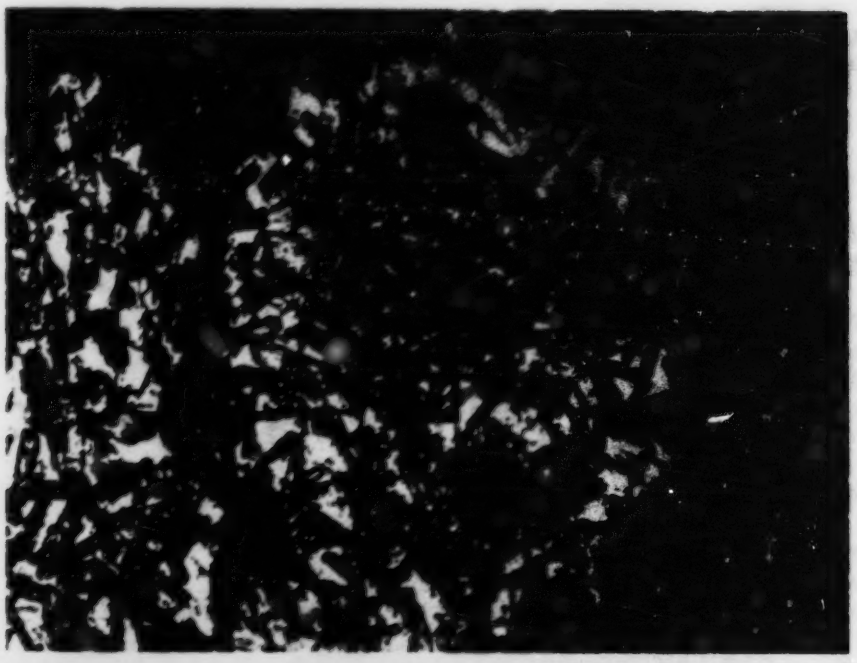


Plate 10: *Photomicrograph of plagioclase phenocryst largely replaced by prismatic zoisite in a matrix of amphibolitized metabasalt, from Coal Brook. 81-LC-25. Plane polarized light.*

mapped as undivided amphibolite. The term amphibolite refers to metamorphic rocks composed of hornblende and plagioclase. This assemblage may form under a wide range of metamorphic conditions, which might be expected to differ in different parts of the area. Therefore, the undivided amphibolites will be described according to location (Figure 2).

Stag Hill high strain zone

Amphibolites of this zone grade north and westward into the transition zone between the layered metagabbro and massive metagabbro and metadiabase, and thus may have been derived from both. Since metasedimentary rocks also occur in this zone, it is probable that some of the amphibolites are derived from mafic metavolcanic rocks and dikes.

Pinstripe banding, formed by the segregation of light from dark colored minerals on a scale of one to several grains, is well developed. The alternation of fine and coarse grained layers, and of dark hornblende with paler green diopside-rich layers, is displayed in some exposures. Plagioclase-rich amphibolites which originally contained coarse ferromagnesian grains, are characterized by ferromagnesian augen. The foliation of amphibolites at the northeast end of the zone is particularly strong. In many outcrops, amphibolites are interlayered with blastomylonitic red granitoid rocks from which they could not be separated on the map.

Most of the amphibolites consist of blue-green hornblende, pale green to beige clinopyroxene (may be salite or diopside), plagioclase, local cummingtonite, clinozoisite or epidote, and local quartz, with accessory apatite, sphene, allanite and local opaque minerals. The blue-green hornblende is moderately to strongly pleochroic. Diopside is generally pale green, and may be either concentrated in selected layers or lenses or disseminated

Plate 11: *Metabasalt or metadiabase (1d) with plagioclase phenocrysts in north-central high strain zone.*

Plate 12: *Breccia of mafic metavolcanic rocks and dikes (1d) intruded by tonalite in north-central high strain zone.*

throughout the rock (Plate 13). It occurs as equant anhedral grains, commonly rimmed with thin coronas of epidote or clinozoisite. Beige clinopyroxene patches with remnant diallage, surrounded by clear, pale green diopside grains, may be the remnants of subophitic igneous augite grains. Plagioclase (andesine to labradorite) forms planar to lensoid aggregates with curved or sutured intergrain boundaries. Some of the plagioclase is replaced by epidote, zoisite or clinozoisite. Colorless and polysynthetically twinned cummingtonite apparently replaces blue-green hornblende in selected layers. Magnetite is the predominant accessory opaque mineral, but minor partly oxidized pyrite was observed in some specimens. Tiny quartz domains (0 to 1 modal per cent) locally occupy plagioclase-plagioclase boundaries.

A layered amphibolite wedge in the north part of the zone (le/b) displays color banding reflecting variations in modal plagioclase on the same scale as the layered cumulate sequence to the southwest. Ultramafic bands occur within this wedge.

A magnetite-rich pegmatite is composed of coarse igneous brown hornblende and clinopyroxene interstitial to coarse, slightly sericitized plagioclase (An_{40}) and abundant anhedral magnetite (up to 25 modal per cent). Clinopyroxene is commonly rimmed or mottled with brown hornblende. Many clinopyroxene grains are uralitized, and rimmed with more deeply pleochroic blue-green hornblende. A clinopyroxene metagabbro hosting the pegmatite consists primarily of plagioclase subophitically enclosed in clinopyroxene and igneous brown hornblende, which in places rims magnetite, and is heavily fractured, the large fractures lined with fine grained chlorite. Deformed clinopyroxene grains are rimmed with igneous brown hornblende which also locally forms very fine films along some of the deformational subgrain boundaries. Clinopyroxene is locally

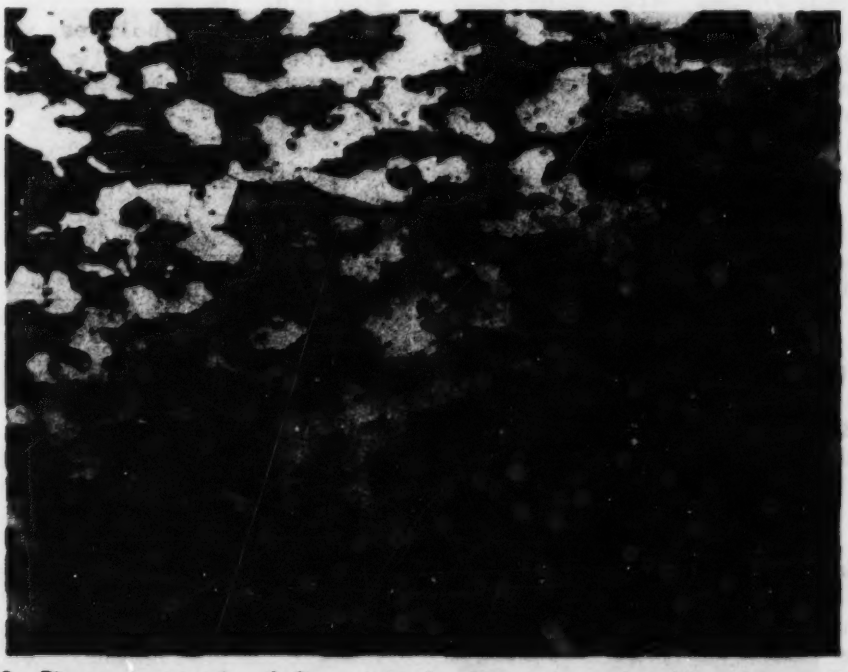


Plate 13: *Photomicrograph of fine grained, clinopyroxene(cpx)-bearing amphibolite from the southwest half of the Stag Hill high strain zone near Little Codroy Brook. 80-LC-419. Plane polarized light.*

replaced in part by pale uralite rimmed with more deeply pleochroic, blue-green amphibole.

Long Range high strain zone

Amphibolites in the Long Range high strain zone are gradational into massive metagabbro and metadiabase in some cases and into mafic metavolcanic rocks in others. They range from very fine to very coarse grained.

Many of the fine grained amphibolites display a pronounced linear fabric, produced by alignment of acicular amphibole crystals. Strong planar fabrics imparting a striped effect have resulted from the deformation of large ferromagnesian grains in some of the coarse grained amphibolites. Most medium grained amphibolites possess a foliation composed of two intersecting S-L fabrics defined by stubbly hornblende and crenulated leucocratic stringers.

The amphibolites are generally composed of blue-green to green hornblende and plagioclase with or without minor quartz. Epidote group minerals, sphene, chlorite, green biotite, magnetite and apatite are common accessory minerals, many of them retrogressive. Some of the coarse grained amphibolites have relict igneous clinopyroxene.

Mylonitic amphibolite along late cataclastic zones contains sparse plagioclase and blue-green hornblende porphyroclasts in a strong planar fabric defined by actinolite, leucoxene or sphene, epidote, chlorite, and ribbons of very fine grained, recrystallized quartz.

Cape Ray Fault zone

The amphibolite along the northwest side of the Cape Ray Fault weathers black, and is fine to medium grained. It lacks the pronounced mineral alignment typical of the other amphibolites, but displays an anastomosing, inhomogeneously developed schistosity which increases in intensity toward the fault.

These rocks consist of inequigranular, greenschist facies assemblages of actinolite, epidote, chlorite, altered plagioclase, minor quartz, and accessory magnetite, pyrite, zircon, and apatite. Actinolite and chlorite define the foliation. The amphibole is fibrous to bladed in many rocks, but may occur as clots of stubbly, prismatic grains in relatively unfoliated rocks. Rare flakes of partly chloritized red-brown biotite occur in the latter. As in nearby massive clinopyroxene metagabbros, the plagioclase is partly to totally replaced by coarse epidote minerals and flakes of muscovite. Pyrite is partly oxidized.

North-central high strain zone

The undivided amphibolite in the north central high strain zone is fine grained. With the exception of a few xenoliths in the southeast part of the zone, the amphibolites lack foliation. The rocks were barely examined in thin section.

One specimen examined is composed of pale brown hornblende, cummingtonite, plagioclase, red-brown biotite, and quartz with accessory magnetite and pyrite. The ferromagnesian minerals are partly chloritized. Cummingtonite and bytownite intergrowths vein the sample.

Highly sheared and retrograded gedrite or anthophyllite schist (Plate 14) occurs locally along the western margin of the high strain zone.

Relative age and origin

The Long Range Mafic-Ultramafic Complex is intruded by foliated tonalite and other granitoid rocks (4), and by younger intrusive rocks (6, 7, 10, 11). Contacts between metasedimentary rocks (2) and the mafic complex approximately coincide with and are obscured by

Plate 14: *Retrogressed anthophyllite or gedrite schist next to the western margin of the north-central inclusion zone.* **14a**: *View of surface perpendicular to schistosity.* **14b**: *View of surface parallel to schistosity, showing radiating anthophyllite or gedrite crystals.*

intense deformation within the major regional structures, the Long Range and the Stag Hill high strain zones; they are also obscured by the intrusion of voluminous granitoid rock. The absence of intrusive contacts or of partly assimilated screens and xenoliths of metasedimentary rock in the mafic meta-igneous rocks, and the lack of hornfels textures in the metasedimentary rocks suggests that the Long Range Mafic-Ultramafic Complex was not intrusive into the metasedimentary sequence as originally suggested by Phair (1949), but is assumed here to be older. Brown (1976b, 1977) similarly suggested that thickly layered and massive amphibolites, correlated during this project with the Long Range Mafic-Ultramafic Complex itself, are the oldest rocks in the terrane northwest of the Cape Ray Fault (see Appendix I).

Despite the obvious tectonic dissection of the complex, the sequence from layered metagabbro through massive metagabbro and metadiabase to mafic metavolcanic rocks and dikes is consistent throughout the map area. The close spatial association of marble and other metasedimentary rocks with mafic metavolcanic rocks and dikes within the Long Range high strain zone, and of marble and paragneisses with undivided amphibolite in the Stag Hill high strain zone, is consistent with the association of mafic metavolcanic and mixed metasedimentary xenoliths in the granitoid rocks of the north-central high strain zone. If the xenolith assemblage of the intrusive granitoid terrane is considered a fairly direct sample of the host terrane, a close spatial association between the mafic metavolcanic rocks and dikes with the metasedimentary rocks suggests a consistent sequence from massive gabbro and diabase through extrusive and hypabyssal rocks to sedimentary rocks prior to deformation.

The Long Range Mafic-Ultramafic Complex has been interpreted as part of an ophiolite sequence, segments of an early Paleozoic oceanic crust and upper mantle (Brown, 1976b). Mafic meta-igneous rocks exposed in the Grandys Lake area, as well as those described to the west and southwest (Phair, 1949; Brown, 1976b, 1976c), are remarkably similar to the gabbroic portions of the Bay of Islands ophiolite (Smith, 1958; Church and Stevens, 1971; Williams, 1975; Malpas and Stevens, 1979) and the Annieopsquotch ophiolite complex (Dunning and Herd, 1980; Dunning, 1980). The layered metagabbro is comparable to the 'critical zone' cumulate layered gabbro, and the massive metagabbro and metadiabase is comparable to the high level isotropic gabbros of both sequences. Typical ophiolitic sequences exposed elsewhere in western Newfoundland are illustrated in Figure 4.

The large volume of cumulate metagabbros, their pervasive granulite facies foliation, and the apparent lack of sheeted dikes suggests formation of the ophiolite at a rapidly spreading ridge (Sleep, 1975). Rapid spreading would also be manifested by a high geothermal gradient.

2.3 Metasedimentary rocks north of the Cape Ray Fault (Unit 2)

Unit 2 includes all of the medium to high grade metasedimentary rocks between the Long Range and Cape Ray Faults. Semipelitic paragneiss (2a) occurs in the Little Codroy Pond belt, marble (2b) occurs largely in the Little Codroy Pond belt, and assorted metasedimentary inclusions (2c) occur in the Dinosaur Pond belt (Figure 5).

Paragneiss (Unit 2a)

Unit 2a consists of semipelitic paragneiss and migmatite folded and faulted with mafic meta-igneous rocks, marble and amphibolite. Coarsely garnetiferous biotite-muscovite-sillimanite schist predominates, and with granodioritic to tonalitic veinlets comprises a well segregated paragneiss. These rocks are retrograded in many

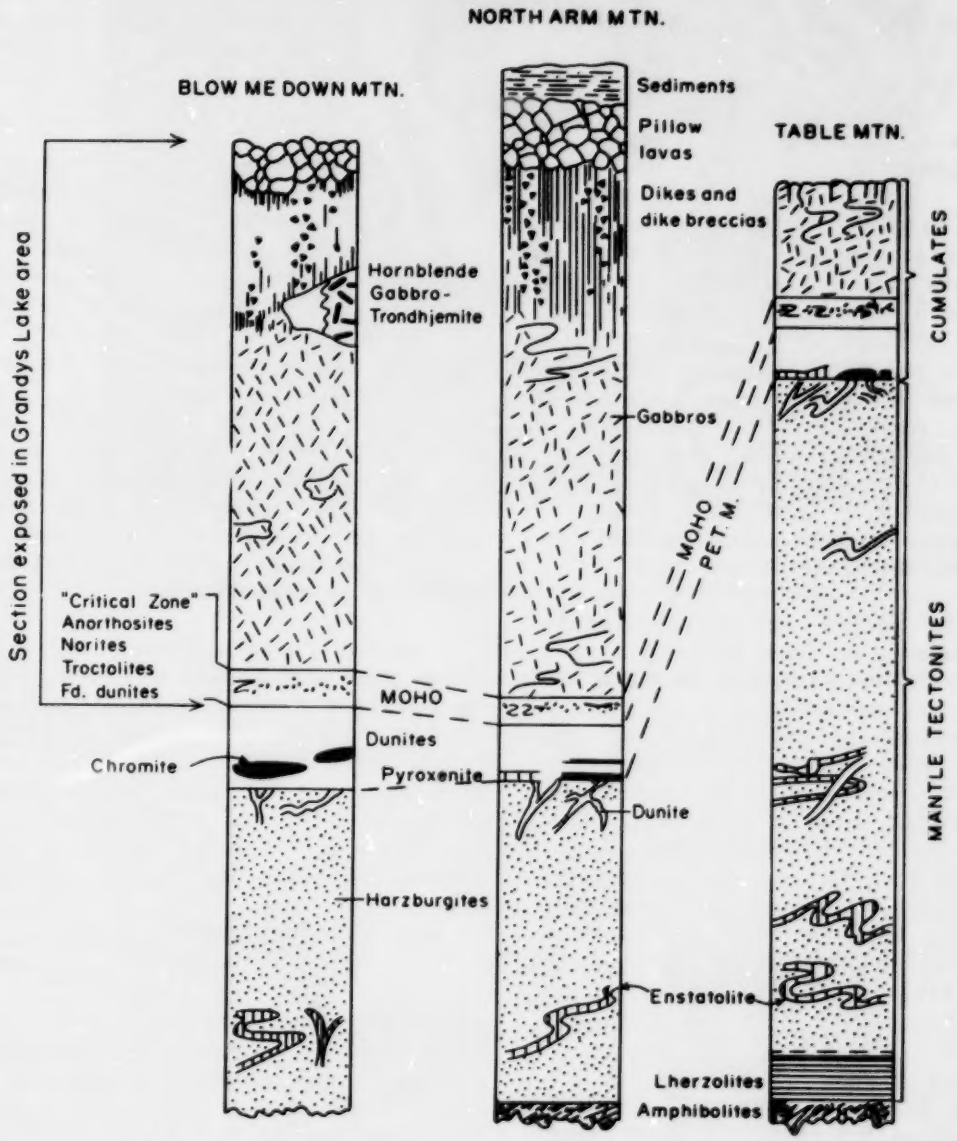


Figure 4: *Sequence of rock types in the Bay of Islands ophiolite (Malpas and Stevens, 1977), indicating parts of the sequence exposed in the Grandys Lake area.*

places within the Long Range high strain zone and at the southeast boundary of the Stag Hill high strain zone.

The paragneisses are generally composed of red-brown biotite, muscovite, garnet, sillimanite, quartz, plagioclase, and local microcline and myrmekite with accessory zircon (with intense haloes in biotite), graphite, and other opaque minerals, mainly magnetite. Locally biotite, muscovite, fibrolitic sillimanite, and thin quartz-feldspar stringers define a strong, penetrative schistosity, which is crenulated or transposed, and within which garnet and rare, large sillimanite crystals form augen. Garnets form augen within the schistosity, and quartz, biotite, and local fibrolite or muscovite fill tension gashes and pressure shadows. Many of the garnet fragments thus produced are offset by the crenulation (Plate 15).

Muscovite occurs as poikiloblastic flakes, domains, as fine grained flakes generally parallel to the penetrative foliation, and as domains of matted sericite which possibly replaced aluminosilicate crystals. Garnets are generally elongated within the foliation plane, and contain random plagioclase, quartz, biotite, and magnetite inclusions; rare staurolite inclusions were observed in the garnets.

Sillimanite generally forms mats and aggregates of fibrolite crystals, or associated with quartz in pressure shadows. In some samples, remnant single crystals of sillimanite several millimetres in diameter are bent and fractured; fibrolite crystals occur along the margins and along fractures.

Feldspar and quartz occur together in thin veinlets with minor muscovite and fibrolite. Plagioclase is ubiquitous, and is corroded by large and small quartz grains. Relatively large microcline grains are either rimmed or corroded by myrmekite.

Banded carbonate-rich and garnetiferous semipelitic schists, locally associated with marble and mafic meta-

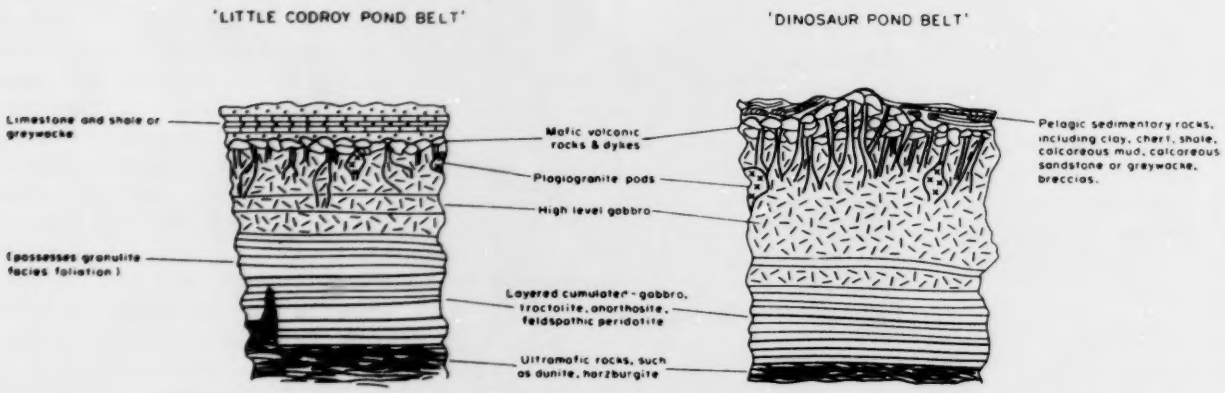

'LITTLE CODROY POND BELT'
'DINOSAUR POND BELT'
Limestone and shale or greywacke
(possesses granulite facies foliation)
Mafic volcanic rocks & dykes
Plagiogranite pods
High level gabbro
Layered cumulate - gabbro, troctolite, anorthosite, feldspathic peridotite
Ultramafic rocks, such as dunite, harzburgite
Pelagic sedimentary rocks, including clay, chert, shale, calcareous mud, calcareous sandstone or greywacke, breccias.

FIGURE 5: *Ophiolitic sequences of the Little Codroy Pond and Dinosaur Pond belts before imbrication, the development of the high strain zones, and the generation of synkinematic granitoid rocks. Vertical sections not to scale.*

Plate 15: *Photomicrograph of garnetiferous gneiss of Unit 2a, showing garnet (gt) fragmented in crenulation schistosity. View approximately perpendicular to rodding lineation at Stag Hill. 80-LC-116. Plane polarized light.*

volcanic rocks respectively, occur near the the Long Range Fault. The rocks are intensely sheared and locally retrogressed, containing chlorite and muscovite in place of biotite. Red, foliated granite injections are common. The carbonate-rich schist contains, in addition to calcite and detrital quartz, vesuvianite, red-brown biotite, scapolite, actinolite, tourmaline, sphene, and graphite.

The quartzofeldspathic mylonite along the southeast margin of the marble band is composed of quartz, alkali feldspar, sillimanite, biotite, and garnet with accessory opaque minerals and coarse zircon. The mylonitic foliation is defined by ribbons of recrystallized quartz, red-brown biotite, fibrous sillimanite, elongate grains of alkali feldspar, and acicular or platy opaque grains. Garnet grains form augen within the foliation, and some grains appear to be fragments strung out in the foliation plane (Plate 16). Quartz inclusions in the garnets are large and locally coalesce with the external matrix, imparting a dendritic appearance to the garnet. Both twinned and untwinned alkali feldspar grains occur as elongate or equant grains embayed by quartz. Many of the elongated grains are cross-cut by curved fractures marked by red-brown iron oxide in some grains and by a high relief, colorless to pale green mineral (fibrolite?) in others.

A pronounced, gently east plunging rodding lineation parallel to both the long axes of mineral boudins and fold hinges is displayed at Stag Hill. An en echelon row of hills northeast of Stag Hill exposes folded, veined paragneiss as a megabreccia; the axial planes of the folds strike northwest in some blocks, northeast in others, suggesting that the veining and folding predated the brecciation.

Plate 16: *Photomicrograph of fragmented garnet augen, offset in crenulation schistosity of quartzofeldspathic blastomylonite adjacent to marble band at the junction of the Long Range and Stag Hill high strain zones. 80-LC-349. Plane polarized light.*

Marble (2b)

Massive marble and calc-silicate rock occurs as a multiply folded band and boudinaged lenses in the high strain zones of the Little Codroy Pond belt, and as rare brecciated rafts in the granitoid rock of the north-central high strain zone in the Dinosaur Pond belt. The marble accompanies other metasedimentary rocks and either mafic metavolcanic rock or undivided amphibolite. It is locally intruded by veins of granitoid rock (Plate 17) and pegmatite.

The marble occurs as thick, layered units composed of white, fine grained calcite with bands and lenses of resistant, yellow weathering, fractured, coarsely crystalline calcite. Gray weathering diopside-rich bands are also present in many exposures. The compositional layering probably represents bedding which was completely transposed during early deformation; inhomogeneous recrystallization also gave rise to contrasting grain size. The layering is openly folded near the base of the Long Range escarpment and steeply dipping at the top. It is folded and boudinaged within the Stag Hill high strain zone.

The white marble is composed mainly of calcite with accessory white mica, graphite, and less commonly, hematite (oxidized pyrite?). Detrital quartz and/or plagioclase is a common minor constituent (Plate 18); the latter is partly altered to scapolite.

The gray marble is composed dominantly of calcite with bands rich in diopside and locally sphene. White mica and quartz is ubiquitous. Graphite is the major accessory mineral.

The buff weathering marble is composed of calcite with subordinate diopside, red-brown phlogopite or biotite, and scapolite (replacing plagioclase) with accessory graphite and tourmaline (dravite).

Plate 17: *Marble along bank of South Branch River, showing banding and boudinaged red granite vein (4d).*

Plate 18: *Weathered outcrop from northern Stag Hill high strain zone showing detrital quartz and plagioclase as resistant fragments.*

Metasedimentary inclusions (2c)

Metasedimentary inclusions in the garnetiferous tonalite of the north-central high strain zone are placed in Unit 2c.

The xenoliths include nonlaminated and laminated garnetiferous biotite paragneiss, banded calcareous schist, microcrystalline garnet-quartz rock, gray metasandstone, and siliceous schist. Outcrops of gneissified breccia composed of angular fragments of laminated semipelitic to slightly calcareous paragneiss were observed locally. The xenoliths and their enclosing tonalite are metamorphosed to upper amphibolite (sillimanite) grade during regional deformation, which involved the formation of composite fabrics, i.e. crenulated schistosity to gneissosity. Some of the ferromagnesian-rich inclusions in the northern part of the area have formed bimetasomatic reaction rims (Plate 19). This occurred during or after the main deformation, since fractures and tension gash boundaries formed during the boudinage of the fragments are also rimmed.

The garnetiferous paragneiss is generally enriched in biotite relative to the enclosing granitoid rock, and is locally layered or more fine grained than the granitoid. In some outcrop areas, the garnetiferous paragneiss inclusions neither display textures that contrast greatly with those of their hosts, nor contrast sufficiently in mineralogy to enable an assessment of the proportion of paragneiss to granitoid present.

The garnetiferous paragneiss is composed of garnet, red-brown biotite, quartz, plagioclase, sillimanite, and local cordierite with accessory opaque minerals (magnetite and pyrite) and clear zircon. Secondary muscovite, chlorite, and carbonate occur locally. A crude segregation of biotite and sillimanite defines a weak to strong schistosity or gneissosity (Plates 20, 21) which is folded in many samples. Garnets either form large, anhedral grains with inclusions of quartz and magnetite, or form tiny euhedral, inclusion-free grains. Locally, the garnets form augen in the planar gneissic fabric defined by sillimanite segregation (Plate 20). Quartz forms large, weakly strained domains which embay plagioclase. Andesine is commonly heavily sericitized. Acicular sillimanite (Plate 21) is locally aligned to impart a linear fabric; it is partly altered to sericite or muscovite. It is mainly, but not solely, associated with the ferromagnesian segregations. Cordierite, where present, occurs as large poikilitic grains which enclose euhedral garnets. Secondary muscovite is generally associated with either chloritized biotite or carbonate patches overprinting plagioclase.

The calcareous schists are laminated or banded, and associated with granitoid rocks particularly rich in red garnet. The banded calcareous schist contains quartz, vesuvianite, calcite, chlorite, and minor rutile with accessory apatite and zircon. Quartz occurs as amoebic to cuspate grains, and as lens-like domains parallel to the banding.

The microcrystalline garnet-quartz rock occurs as pink to blood-red, chunky xenoliths up to fist size, which lack internal structure. It consists of about 70 per cent pink to red garnet and about 20 per cent quartz with minor brown biotite, muscovite, ferristilpnomelane, and abundant disseminated magnetite. Garnets form solid patches and open networks of rounded grains well under 0.05 mm in diameter, and polygonal quartz is interstitial. Flakes of muscovite and chlorite, and fine grained ferristilpnomelane patches occur in the quartz network.

The gray metasandstone consists essentially of quartz, plagioclase, and amphibole with abundant accessory magnetite, xenotime, sphene, zircon, and pyrite. Clinozoisite, zoisite, coarse

Plate 19: *Assorted metasedimentary (2c) and amphibolitic (1e) inclusions in metatonalite (4b) showing bimetasomatic reaction rims.*

Plate 20: *Photomicrograph of garnet(gt)- and sillimanite(sil)-bearing gneiss of Unit 2c, showing garnet augen in strong gneissosity defined by sillimanite. 80-LC-190. Plane polarized light.*

Plate 21: *Photomicrograph of garnet(gt)- and sillimanite(sil)-bearing gneiss of Unit 2c, showing sillimanite segregated along crenulation schistosity or gneissosity. 80-LC-223. Plane polarized light.*

muscovite, and patchy carbonate overprint plagioclase especially near late fractures. The predominant amphibole is very pale green, fibrous tremolite. Clear, high relief clinopyroxene(?) is preserved as remnants within of amphibole.

The siliceous schist shows no recognizable primary features. It is composed of quartz, biotite, cummingtonite, and gedrite with accessory fine grained opaque minerals and apatite. Quartz is most abundant, and forms ribbon-like, polygonized stringers parallel to the schistosity. Red-brown biotite, cummingtonite, and gedrite occur in subequal proportions as oriented segregations between the quartz domains.

The southeast part of the zone is locally more highly strained and metasomatically altered. The rocks contain muscovite, epidote minerals, and local kyanite, as well as garnet additional to quartz, plagioclase garnet, sillimanite, and biotite. The most highly strained rocks, which form rusty weathering, scaly mounds, are very fine grained. Quartz overprints all minerals (Plate 22). Biotite is completely leached to pale colored unidentified mica profusely decorated with ilmenite. Ragged porphyroblasts of muscovite and bundles of fibrolite are common locally. Plagioclase is partly sericitized, muscovitized, or fibrolitized. Rare crystals of kyanite occur in rocks containing fibrolite bundles. Large skeletal to poikilitic garnets with quartz inclusions are commonly surrounded by zones lacking ferromagnesian constituents (Plate 22). Opaque minerals are highly oxidized or leached. Less highly strained rocks in this area are medium to coarse grained. Garnets contain abundant inclusions of quartz, plagioclase, biotite, opaque minerals, fibrolitic sillimanite, and rare ferristilpnomelane aggregates. Polycrystalline garnet clots, similar to

Plate 22: *Photomicrographs of polkilitic garnet (gt) in highly sheared (rusty) outcrop, showing ferromagnesian-poor rim around garnet and abundance of fine grained quartz (q). 22a: Plane polarized light, best showing polkilitic garnet and ferromagnesian-depleted rim. 22b: Cross polarized light, best showing fine grained overprint of undeformed quartz.*

the microcrystalline garnet-quartz rocks described above, appear in a few samples. Plagioclase is largely replaced by muscovite (cf. Plate 41) and/or locally overprinted by clinozoisite.

Varying degrees of partial retrogression are displayed within the zone, generally around fractures and lineaments. Intense retrogression, linked with movement along the western fault boundary, resulted in chlorite and muscovite replacing biotite-sillimanite segregations of the early gneissic fabric.

Relative age and origin

The metasedimentary rocks northwest of the Cape Ray Fault are intruded by foliated granitoid rocks locally generated *in situ*. In the absence of evidence to the contrary, it is suggested that the metasedimentary rocks were deposited upon the Long Range Mafic-Ultramafic Complex and were not intruded by it, and that only the extrusive and hypabyssal portions of the Long Range Mafic-Ultramafic Complex were exposed at the time of deposition. Tentative stratigraphic columns for the Little Codroy Pond belt and the Dinosaur Pond belt are given in Figure 5. The proximity of relatively deepseated parts of the Long Range Mafic-Ultramafic Complex to metasedimentary rocks within the Long Range and Stag Hill high strain zones may partly result from tectonic thinning due to early thrust faulting (Figure 6), an effect enhanced by late deformation. However, the occurrence of the only recognizable mafic metavolcanic rocks and dikes next to metasedimentary rocks in both the Long Range and the north-central high strain zones indicates a regular progression from intrusive through hypabyssal to extrusive/sedimentary environments.

Suggested protoliths for the semipelitic and calcareous paragneisses and schists of Unit 2a and similar xenoliths of Unit 2c include graywacke, quartzitic sandstone, siltstone, calcareous mudstone, and shale; for Unit 2b, banded limestone. The more exotic metasedimentary inclusions of Unit 2c, such as the microcrystalline garnet-quartz rock and the cummingtonite- and gedrite-bearing siliceous schist, may have been associated with submarine weathering of volcanic rocks and/or sea floor hydrothermal activity. Some of the associated inhomogeneous, cummingtonite- and biotite-bearing amphibolite/metavolcanic inclusions possibly represent mafic volcanic rocks affected by submarine weathering. Umber, ochre, red iron-rich clay, chert, tuff, calcareous o siliceous muds and breccias as well as shale and sandstone are possible protoliths for the wide variety of metasedimentary inclusions in this zone. Single analyses for the microcrystalline garnet-quartz rock and the siliceous schist are reported below (Table 3).

It is noteworthy that the garnetiferous tonalite includes metasedimentary assemblages as well as mafic metavolcanic rocks as xenoliths where it sites several very rusty shear zones.

Table 3: Analyses of microcrystalline garnet-quartz rock (80LC186) and cummingtonite- and gedrite-bearing siliceous schist (80LC198)

(wt%)	SiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Na_2O	K_2O	TiO_2	MnO	P_2O_5	LOI
80LC186	58.2	12.90	10.23	10.83	2.09	2.31	.13	.10	1.28	.78	.22	nil
80LC198	82.0	6.25	.13	2.90	3.12	1.57	.22	.85	.38	.07	.11	1.89

(ppm)	Ba	Sr	Rb	Cr	V	F	Cu	Zn	Ni	Li	Mo	Pb
80LC186	58	29	3	34	127	156	11	144	35	4	3	nd
80LC198	177	54	20	521	67	1255	6	47	91	18	3	2

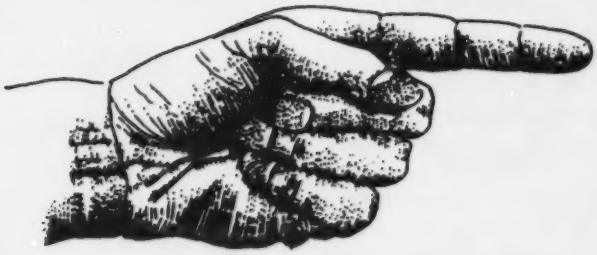


Figure 6 is not available at time of printing and is therefore included in the pocket.

2.4 Metasedimentary rocks and amphibolite south of the Cape Ray Fault: modified Bay du Nord Group (Unit 3)

Metasedimentary rocks (3a,b) and amphibolite (3c-f) south of the Cape Ray Fault are here informally included in the modified Bay du Nord Group (Chorlton, 1980b) pending revision of the regional lithostratigaphic nomenclature (see Appendix I). Radiometric data indicate a middle or late Ordovician age for metavolcanic rocks within this group southeast of the map area (Dallmeyer, 1979, 1981; Chorlton, Dallmeyer and Odom, in preparation).

The group hosts numerous sheets of highly deformed synkinematic granitoid rocks over the west half of the area. They pass eastward into a mixed zone of granitoid rocks and metasedimentary rocks and amphibolite, and thence into an eastern granitoid terrane where metasedimentary and amphibolitic rocks form only inclusions and screens. Therefore, the boundary between the granitoid rocks and 'Bay du Nord Group' is shown as gradational on the accompanying map.

Metasedimentary rocks (3a,b)

The metasedimentary rocks consist largely of semipelitic schist and migmatite (3a) with thin calc-silicate bands, and garnet-staurolite-kyanite schist (3b) with thin coticule (microcrystalline garnet-quartz) bands. Unit 3b is gradational into Unit 3a.

Primary compositional banding is reflected by relatively quartzitic layers, garnet-rich grading into garnet-poor layers, and calc-silicate bands. A strong segregation fabric (S_0 parallel to S_1 and in places S_2) is developed east of Northwest Brook (Plates 23, 24). Anatectic quartz-oligoclase-muscovite veins and quartzitic sweats postdated the first deformation, and are generally concordant to and multiply folded with the compositional banding and earliest schistosity (Plate 23).

Plate 23: *Complex folding in migmatitic gneisses of Unit 3a west of Northwest Brook.*

The semipelitic schist/gneiss is composed largely of quartz, unaltered plagioclase (oligoclase-andesine), dark olive brown biotite, muscovite, local garnet, and local sillimanite with accessory apatite, zircon, magnetite, and rare graphite. The fabric is defined by preferred orientation of biotite and muscovite and the dimensionally preferred orientation of quartz and feldspar. Muscovite occurs locally as large, ragged porphyroblasts and polycrystalline clots. It is also locally converted to fibrolite. Garnets are very small, and tend to form augen within the S_2 schistosity. Plagioclase in the veins is heavily occluded.

The calc-silicate bands of unit 3a contain quartz, plagioclase, red-brown biotite, blue-green hornblende, and zoned epidote and allanite with accesory sphene, apatite, zircon, and pyrite. Blue-green hornblende forms patches of inclusion-free to poikilitic prisms locally cross-cut by biotite. Epidote forms large, colorless, prismatic grains, many with cores of brown allanite. Rare poikiloblasts of plagioclase were also observed.

The garnet-staurolite-kyanite schists (3b) are composed largely of quartz, biotite, staurolite, almandine garnet, kyanite, plagioclase, local muscovite, and minor fibrolitic sillimanite (Plates 24-29). Minor chlorite occurs as a late secondary mineral. Zircon, magnetite, apatite, local rutile and rare tourmaline (schorl) are accessory minerals. The main schistosity is defined by brown biotite in most of the rocks, but by biotite, muscovite, and kyanite or fibrolite in others. Dimensionally oriented, strained quartz and subordinate plagioclase (oligoclase-andesine) also define this fabric. S_2 appears to be locally axial planar to tight folds of the earlier compositional fabric or banding (S_0 parallel to S_1), and is conspicuously crenulated to openly folded (D_3) (Plates 26 to 29).

The proportions and grain size of staurolite, garnet, kyanite, biotite, and muscovite vary from layer to layer. Staurolite grains several centimetres long enclose abundant planar to slightly curved inclusion trails of quartz and minor magnetite, and locally enclose garnets (Plate 26). Large staurolites are surrounded by mafic-poor rims of flaser quartz, and have asymmetric, quartzitic to quartzofeldspathic extension fracture fillings and pressure shadows (Plate 26). They form augen within the main fabric (S_2) which is inclined to the plane of the internal inclusion trails (S_1), and are also locally rotated, bent, and annealed in segments by the D_3 crenulation (Plate 30). The largest garnets contain planar inclusion trails of quartz and subordinate magnetite, at an angle to the external schistosity (S_2) within which the garnets form augen. Kyanite occurs as locally twinned, elongate grains oriented along the main schistosity (S_2) (Plates 28, 29). Where the main fabric is folded or crenulated, the kyanite grains are fractured and the fragments rotated by the crenulation (S_3) (Plate 29). Local muscovite/fibrolite fringes occur at the ends of deformed grains. Very fine fibrolite radiates locally from late fractures in the quartzofeldspathic intergrowth.

The coticules in Unit 3b are local thin, contorted bands or lenses composed of 35 to 80 per cent very fine grained garnet in an intergrowth of quartz with traces of biotite (Plates 24, 25). The garnets in the surrounding schist are also very fine, and large numbers are locally included in both kyanite and staurolite.

Amphibolites (3c,d,e,f)

The amphibolites south of the Cape Ray Fault include massive, locally garnet-bearing amphibolite (3c), well layered amphibolitic metagabbros (3d), very fine grained amphibolite (3e), and gedrite-bearing amphibolite and schist. All display strong S-L fabric.

The massive amphibolites (3c) are generally composed of blue-green hornblende and plagioclase with accessory zircon, apatite, and local opaque minerals, sphene or rutile. Prismatic, blue-green hornblende and plagioclase (andesine to labradorite) occur in variable proportions as pinstriped, medium to very fine grained, granoblastic intergrowths (Plate 31). Near the Cape Ray Fault, the hornblende is more deeply pleochroic and defines a stronger fabric than away from it, and either sphene or rutile takes the place of opaque minerals. Tiny, inclusion-free garnets either overprinted or crystallized with the hornblende and plagioclase intergrowth locally.

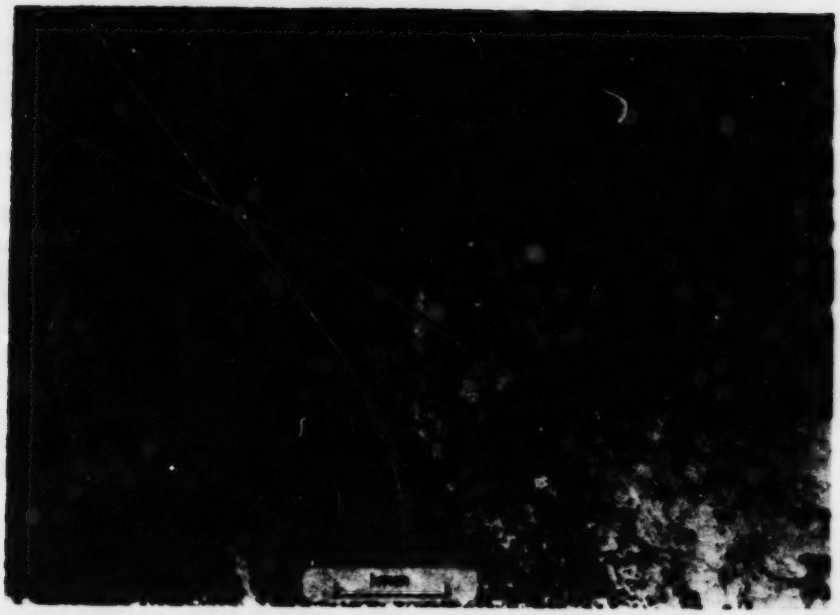


Plate 24: *Photomicrograph of tightly folded (F_2) coticules in staurolite-garnet-kyanite-muscovite-biotite schist (3b). Coticules reflect S_0, quartz inclusion trails in staurolite (st) reflect S_1, and staurolite forms augen in S_2. CW-79-179a. Plane polarized light.*

Plate 25: *Photomicrograph of coticule-bearing, garnet-staurolite-kyanite schist (3b), showing coticule bands and corner of a small, ovoid coticule ball which possibly originated as a clay pellet; also, kyanite (ky) overprinting biotite (bi) along S_1 foliation, transposed parallel to S_2. CW-79-179a. Plane polarized light.*

Plate 26: *Photomicrograph showing staurolite (st) with slightly curved quartz inclusion trails reflecting S_1 and single garnet inclusions forming fragmented augen in S_2 fabric. Quartz fills extension gash. 79-LC-266b. Plane polarized light.*

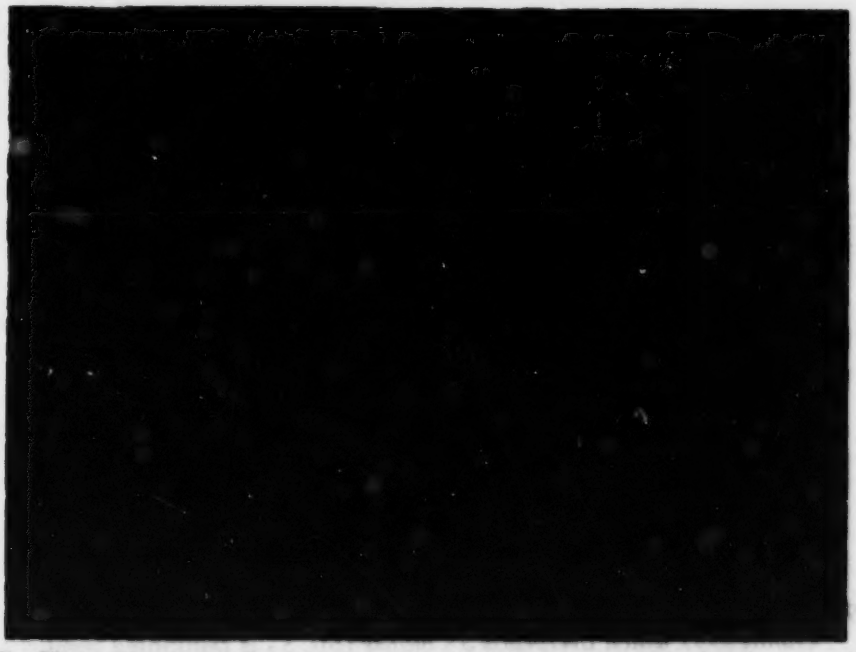


Plate 27: *Photomicrograph showing staurolite (st) fragments offset by D_3 crenulation. 79-LC-276. Plane polarized light.*

Plate 28: *Photomicrograph of garnet-staurolite-kyanite schist (3b) showing layering and early, micaceous schistosity (S_1) tightly folded (F_2) as well as a later micaceous schistosity (S_2). Kyanite (ky) overprints S_1, and quartz inclusion trails in staurolite (st) are concordant with the external S_1. 79-LC-276. Plane polarized light.*

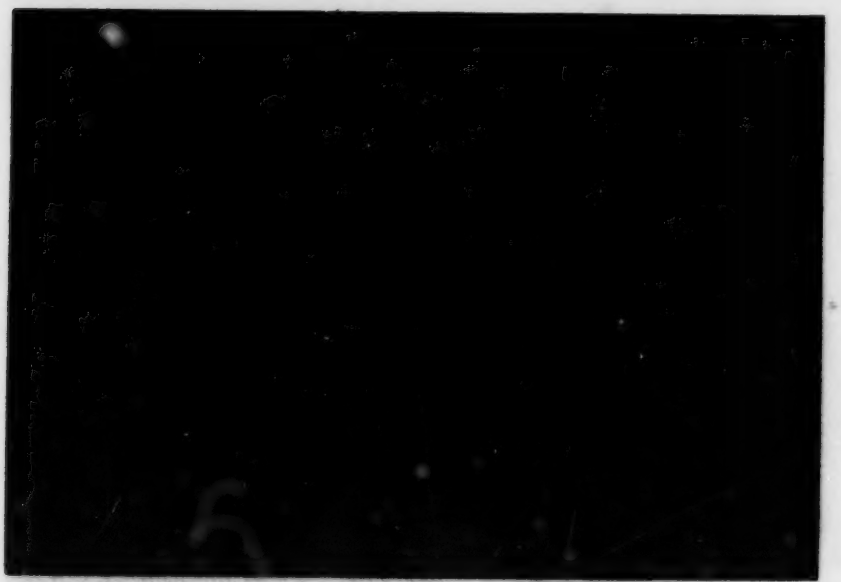


Plate 29: *Photomicrograph of biotite-garnet-staurolite-kyanite schist (3b) showing kyanite (ky) which overprints S_2 biotite (bi). S_1 is transposed parallel to S_2 in limb of F_2 microfold, and is affected by the D_3 crenulation. 79-LC-266b. Plane polarized light.*

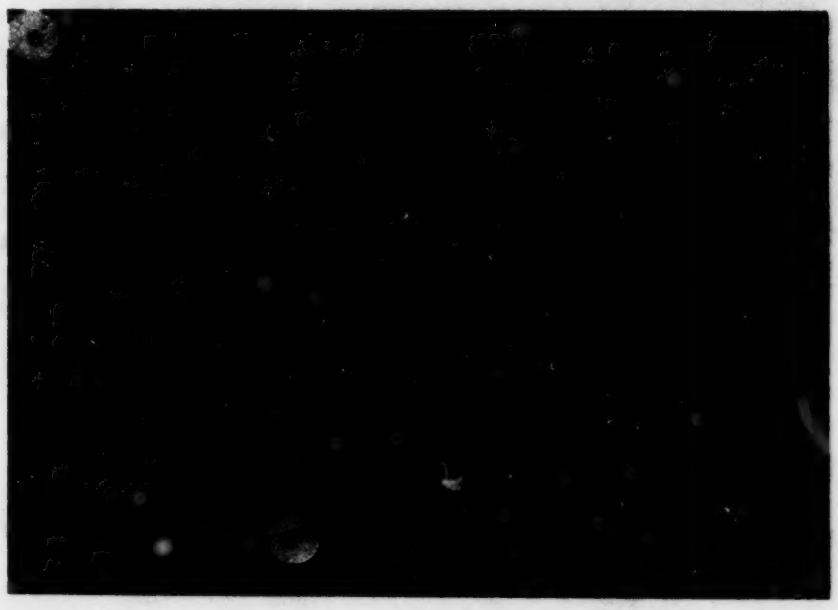


Plate 30: *Photomicrograph showing staurolite (st) bent by D_3 crenulation. 79-LC-276.* **30a**: *Plane polarized light, best showing the bent nature of the single staurolite crystal.* **30b**: *Cross polarized light, best showing reoriented segments of staurolite.*

Plate 31: *Photomicrograph of amphibolite (3c) with pinstripe foliation, composed of lenticular segregations of blue-green hornblende (h) and plagioclase (pg), from Grandys Brook. 79-LC-264. Plane polarized light.*

The layered metagabbros (3d) are composed of variable proportions of plagioclase, blue-green hornblende, and pale green to colorless clinopyroxene with minor sphene and accessory apatite, zircon, and rare opaque grains. They are layered on a scale of 1 cm up to 0.50 m. The layering partly reflects fluctuations in plagioclase content, and partly the hornblende to clinopyroxene ratio. Hornblende and clinopyroxene occur as segregations parallel to the foliation plane and banding, but some clinopyroxene grains occur alone (Plates 32, 33a). Blue-green hornblende predominates as polygonized grains or grain aggregates interstitial to the plagioclase (Plates 32, 33). Clinopyroxene grains are larger where they are more abundant. They lack remnant diallage, and poikilitically enclose or overprint hornblende, sphene and rare plagioclase. They are commonly rimmed by epidote. Plagioclase occurs as granoblastic lenses or networks (Plate 33b), and ranges in composition between andesine and labradorite. It commonly forms marginal embayments in the ferromagnesian minerals (Plate 32). Secondary carbonate patches are concentrated along late fractures which cross-cut the foliation.

Fine grained amphibolite (3e), associated with metasedimentary rocks (3a), is composed of plagioclase (20 to 30 modal per cent), blue-green hornblende (40 per cent), quartz (10 per cent) with minor opaque minerals and abundant secondary epidote and biotite. Apatite is the common accessory mineral. Blue-green hornblende occurs as intensely pleochroic, acicular grains which are aligned in the very fine scale, strong foliation. Plagioclase grains are completely sericitized, and occur in narrow bands which are overprinted by clear quartz grains and stringers. The fabric is randomly overprinted by flakes of olive green biotite and abundant coarse epidote.

Plate 32: *Photomicrograph of coarse grained, layered clinopyroxene-bearing amphibolite (3d) from east of Grandys Brook. Clinopyroxene (cpx) overprints polygonized blue-green hornblende (h), and plagioclase (pg) embays the ferromagnesian aggregates. Thin section was cut parallel main foliation plane. 79-LC-274. Plane polarized light.*

The gedrite-bearing amphibolite and schist (3f) includes gedrite-hornblende-plagioclase and gedrite-plagioclase amphibolites, and gedrite-garnet-biotite-amphibole-plagioclase schist (Plate 34).

Gedrite amphibolites (3f) consisting largely of gedrite, blue-green amphibole, local biotite, and plagioclase grade locally into those consisting solely of gedrite, plagioclase, quartz, and accessory hematite (Plate 35). A strong planar fabric (S_1-S_2) is defined by the inequigranular intergrowth of oligoclase, subordinate quartz, and highly acicular, locally kinked, blue-green amphibole. Spectacular sheaves of acicular, pale brown gedrite crystals up to 4 cm long overgrow the foliation but generally are oriented with their long axes parallel to the foliation plane. The gedrite forms very weak augen within the S_2 schistosity (Plate 36), and is affected by the crenulation S_3 (Plate 37).

The gedrite-bearing schist (3f) consists of blue-green amphibole, gedrite, red-brown biotite, plagioclase, garnet, and quartz with accessory hematite and secondary chlorite (Plates 34, 37). Large, euhedral gedrite crystals cross-cut the strong planar fabric defined by biotite and amphibole (Plate 39), and display quartz-filled extension fractures (Plate 36). They are rotated and slightly displaced by the crenulation cleavage (S_3), as are the large garnets. The amphibole is very acicular, commonly bent or kinked, and shows moderate pleochroism (Z = blue-green; Y = grass green; X = colorless); it may be actinolite rather than hornblende. Plagioclase is slightly more abundant than quartz, is pericline and albite twinned, and approximates andesine in composition.

In one specimen of Unit 3f collected from a mylonite zone along the south side of the Cape Ray Fault, the plagioclase and gedrite form porphyroclasts in feldspathic, mylonitic banding

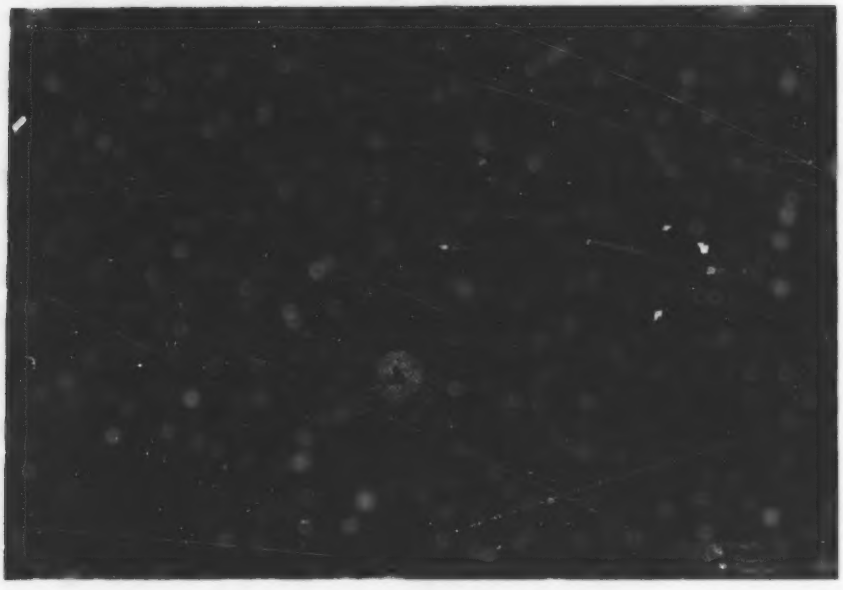


Plate 33: *Photomicrographs of clinopyroxene-bearing amphibolite (3d) showing blue-green hornblende (h) defining strong foliation and overprinted by clinopyroxene (cpx). 80-LC-408a.* **33a:** *Plane polarized light, best showing clinopyroxene alone, and overprinting recrystallized hornblende.* **33b:** *Cross polarized light, best showing granoblastic character of plagioclase (pg) domains, and variable crystallographic orientations of recrystallized hornblende domains.*

Plate 34: *Garnet-gedrite schist (3f). Outcrop surface is parallel to main foliation plane (S_2), displaying garnets and radiating gedrite sheaves. Lense cap is 5 cm in diameter.*

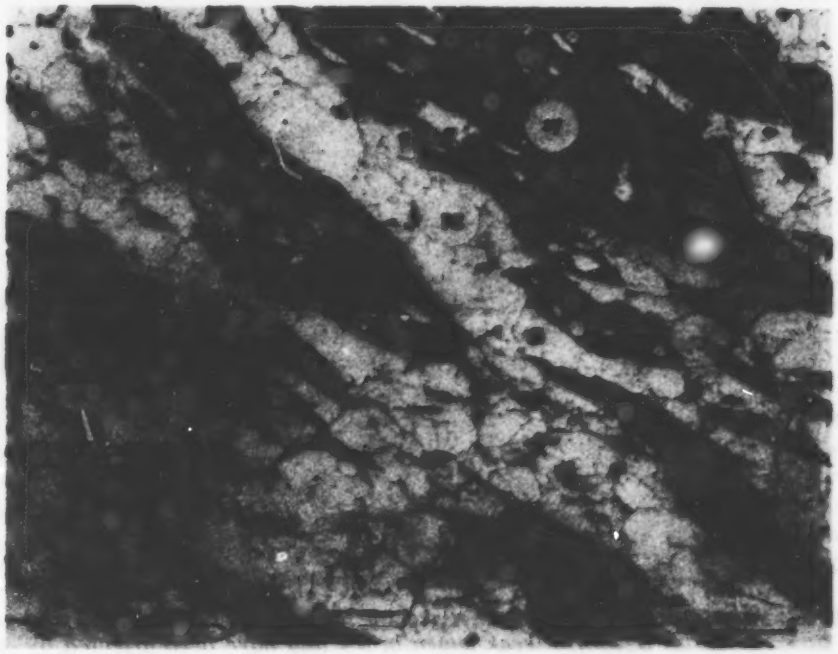


Plate 35: *Photomicrograph of gedrite amphibolite, composed mainly of gedrite (ay) and plagioclase (pg). 80-LC-413. Plane polarized light.*

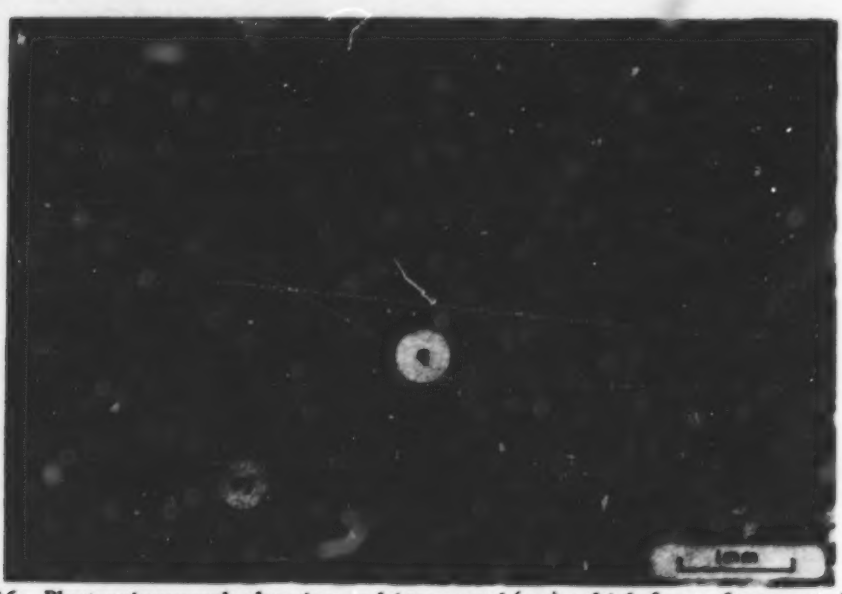


Plate 36: *Photomicrograph showing gedrite crystal (ay), which forms fragmented augen in the S_2 schistosity, weakly crenulated by S_3. Extension gash is filled with quartz (q). CW-79-161. Plane polarized light.*

Plate 37: *Photomicrograph of garnet-gedrite schist (3f). Gedrite (ay) and garnet (gt) overprint S_1, form weak augen in S_2, and have been affected by crenulation cleavage S_3. CW-79-161. Plane polarized light.*

(S_3), and the gedrite crystals are partly replaced (Plate 38) by fibrous chlorite, khaki green biotite, and traces of ferristilpnomelane. Several unaltered gedrite fragments are isolated along the foliation.

Relative age and origin

The Cape Ray Fault system forms the northern contact of the modified 'Bay du Nord Group,' juxtaposing it against the Windsor Point Group and the tonalite terrane. Metamorphic textures suggest that rocks of the 'Bay du Nord Group' were brought to their metamorphic peak, locally partially melted, and intruded by the synkinematic granitoid rocks after D_1, but before D_2 and the juxtaposition of the Windsor Point Group.

The lack of fossils, the tectonic disruption of associated rock units, and metamorphic recrystallization make it difficult to determine the environment of deposition of the metasedimentary rocks. They are represented in this area by predominantly semipelitic to pelitic schist with minor, slightly calcareous bands and relatively quartzitic units which were probably deposited as sediments in a marine basin. The presence of coticules, generally considered the metamorphosed equivalents of thin, iron and manganese rich clay layers weathered in a marine environment (Clifford, 1960; Schiller and Taylor, 1965; Kramm, 1976), is compatible with this origin. Crystallization of the coticule garnets before the prograde metamorphic crystallization of kyanite and staurolite suggests that the garnets nucleated earlier, possibly under lower grade conditions, and thus may have originally been enriched in spessartine. However, the very small grain size (high surface energies) of the coticule garnets makes it likely that they equilibrated with such minerals as biotite and staurolite in the surrounding rock during prograde metamorphism.

Very fine grained amphibolite bands or lenses (3e) probably originated as mafic flows, sills, or dikes in the sedimentary pile, as suggested by Power (1955) and Gale (1967). Some bands or lenses may alternatively represent metamorphically differentiated limestone or marl interbeds in a shale and graywacke sequence (cf. Orville, 1969; Vidale, 1969), but lack of gradation into semipelitic and calc-silicate layers makes this unlikely. However, calc-silicate pods have been reported in amphibolite bands to the south near the Rose Blanche highway (Gale, 1967), and in both areas are tentatively interpreted as originating as boudinaged calcareous sedimentary bands, concretionary pods, and/or carbonate-bearing mafic volcaniclastic rocks.

The thick wedges of amphibolite (3c,d,f) in the west part of this area possibly originated as an oceanic - island arc plutonic basement to the sedimentary terrane (3a, b). The wedges may be highly deformed and recrystallized equivalents of either mafic, ophiolitic/subvolcanic horqts considered basement to the Bay du Nord metasedimentary and metavolcanic rocks around the Blue Hills of Couteau (Chorlton, 1980a, 1980b), or of the ophiolitic Long Range Mafic-Ultramafic Complex northwest of the Cape Ray Fault. Metapyroxenite rafts in the synkinematic and later granitoid rocks (5,9) exposed in Northwest Brook resemble coarse grained, cumulate peridotite patches in the Ernie Pond Gabbro (Chorlton, 1978), a mafic intrusion consisting largely of gabbro and diorite which fed mafic sills and flows in the metavolcanic pile in the La Poile area. A hornblende-biotite metadiorite raft enclosed in the synkinematic granitoid rocks in the same area could similarly be arc-magmatic. Both rafts are protected from strong D_2 deformation by the enclosing, more ductile granitoid rocks, and should be investigated as possible protoliths for some of the highly deformed and metamorphically recrystallized amphibolites.

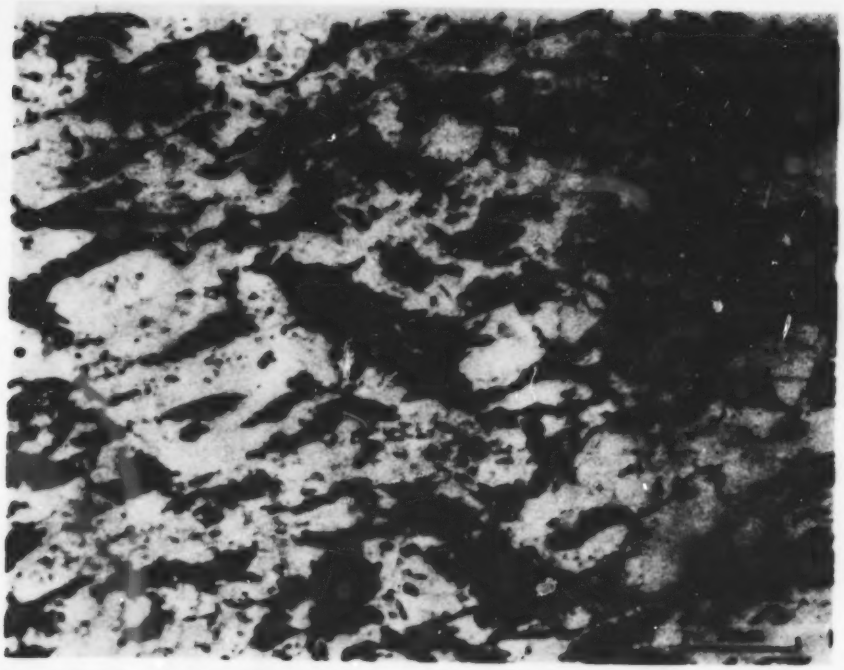


Plate 38: *Photomicrograph of retrogressed, crenulated gedrite amphibolite in which fibrous chlorite has partly replaced gedrite. Near the Cape Ray Fault. 79-LC-280. Plane polarized light.*

Plate 39: *Photomicrograph showing gedrite (ay) overprinting the planar fabric (S_1) defined by blue-green amphibole and red-brown biotite. CW-79-161. Plane polarized light.*

The layering of the layered metagabbros (3d) is similar in type and scale to the layering of clinopyroxene metagabbro (1c,b) at the top of the olivine-bearing cumulate layered metagabbro sequence (1b) north of the Cape Ray Fault.

The origin of the gedrite-bearing amphibolite and schist (3f) is debatable. They may be the result of syndeformational (D_2) hydrothermal alteration or *in situ* weathering of metagabbro during fault movement. Alternatively, they may represent olivine-bearing cumulate metagabbros such as Unit 1b, or feldspathic tuffaceous rocks.

3. ROCKS THAT WERE GENERATED AND EMPLACED SYNMETAMORPHICALLY AS A CONSEQUENCE OF THE EARLY REGIONAL DEFORMATION, AND BELONG TO STAGE 2

3.1 Introduction

The voluminous, foliated, equigranular tonalite, and other granitoid rocks (4) which intrude the Long Range Mafic-Ultramafic Complex and metasedimentary rocks north of the Cape Ray Fault, and the foliated tonalitic, granodioritic, and granitic rocks (5) which cut the modified 'Bay du Nord Group' south of the fault were emplaced early in the tectonic history of the area. Several pegmatites, quartz-kyanite veins, and quartz veins were also generated and emplaced syntectonically in the terrane southeast of the fault.

Southeast of the Cape Ray Fault, the granitoid rocks were synmetamorphic, and emplaced close to their source. This is supported by gravity data for the Port aux Basques phase (Dingwell, 1980). Field and petrographic evidence indicates that the metasedimentary host rocks (3a,b) were brought to low amphibolite facies and higher metamorphic grades following an early penetrative regional deformation episode (D_1) of the southern block prior, but to the intrusion of both Rose Blanche and Port aux Basques phases. The granitoid magmas were emplaced as structurally concordant, lit-par-lit sheets which show no chill or contact effects, and were subsequently deformed with their hosts (D_2) under amphibolite facies conditions.

In contrast, there is no evidence that the pretectonic rocks north of the Cape Ray Fault (1,2) were penetratively deformed before the generation and emplacement of the granitoid rocks (4). Both the granitoid rocks and their hosts in high strain zones were subsequently affected by deformation under amphibolite facies conditions, producing strong composite fabrics. The biotite tonalite (4a), at least, was uplifted and cooled before the emplacement of the Windsor Point Group along the Cape Ray Fault.

A Rb/Sr isochron age of 415±15 Ma for the Rose Blanche Granite of Brown (Brown, 1976b, quoting R. Cormier, personal communication), as well as K/Ar ages of 410±20 Ma (Gillis, 1965) and 415±20 Ma (Neale, 1963) for muscovites from syntectonic pegmatites are tentatively interpreted as reflecting late Silurian to early Devonian deformation (D_2) and regional metamorphism southeast of the Cape Ray Fault. The granitoid rocks north of the Cape Ray Fault are presently considered somewhat older than those south of the fault.

3.2 Tonalite and other foliated granitoid rocks north of the Cape Ray Fault (Unit 4)

Unit 4 includes the voluminous, foliated, equigranular granitoid rocks which intrude the Long Range Mafic-Ultramafic Complex (1) and metasedimentary rocks (2) north of the Cape Ray Fault. The unit includes biotite tonalite (4a), garnetiferous biotite tonalite (4b), garnetiferous tonalite to granodiorite (4c), and pink granite (4d).

These granitoid rocks are characterized either by abundant inclusions, rafts, and screens of host rock or by a lit-par-lit style of intrusion into the host terrane. Each subunit is associated with its own typical host material. The rocks of Unit 4 display penetrative fabrics concordant with the earliest recognized fabrics of their inclusions or hosts, produced under the same metamorphic conditions.

Although these rocks occupy a large proportion of the map area, there are no intrusive relationships among them. Unit 4a is gradational into Unit 4b. Units 4b and 4c are similar in regional metamorphic and structural development; conditions during their postemplacement development may have been similar. Unit 4d has undergone the same tectonic

Plate 40: *Abundant inclusions of metagabbro and metadiabase (1c) in tonalite (4a).*

history as Unit 4c. It is suggested that all four rock types were emplaced at the same general stage of geological development north of the Cape Ray Fault. However, some of the variably deformed pods of red quartz syenite along the Long Range Fault, here included in Unit 4d, may have been emplaced much later.

Biotite tonalite (Unit 4a)

The biotite tonalite (4a) intrudes massive metagabbro and metadiabase, undivided amphibolite, and subordinate mafic metavolcanic rocks and dikes of the Long Range Mafic-Ultramafic Complex. In many areas, the tonalite occurs only as apophyses in the massive metagabbro and metadiabase, but grades into agmatites of tonalite with between 30 and 70 per cent equant to elongate mafic meta-igneous inclusions (Plate 40). The biotite tonalite passes into garnetiferous biotite tonalite (4b).

Unit 4a consists mainly of medium grained, equigranular, biotite trondhjemite and grades locally into biotite tonalite. It is largely composed of plagioclase, quartz, biotite, minor muscovite, and minor to trace amounts of magnetite with accessory zircon, apatite, and pyrite. Modal quartz is inversely proportional to modal biotite. Plagioclase comprises 40 per cent of the tonalite, and occurs as clear, unzoned, subhedral andesine grains in rocks that are not retrograded. Minor, patchy sericitization affects plagioclase locally. Quartz domains are characteristically blue-gray in color. Biotite forms olive green interstitial aggregates. It is locally intergrown with minor muscovite. Ragged muscovite porphyroblasts locally overprint plagioclase. Both biotite and flattened quartz domains define a schistosity, commonly crenulated or cross-cut by a locally predominant secondary foliation. The tonalite in the extreme northeast

part of the area displays a weak gneissosity due to the segregation of biotite. North of Grandys Lake, veins of relatively undeformed, coarse grained trondhjemite locally cut obliquely across the schistosity of the tonalite. Metagabbro and metadiabase inclusions are commonly much less deformed than their tonalite host in the southwest part of the belt.

The biotite tonalite along the northwest side of the Cape Ray Fault has been intensely sheared by the late activity of the fault. It contains abundant secondary chlorite, epidote, carbonate, and sericite. Quartz is strained, polygonized, and locally completely recrystallized into lenses and discontinuous stringers, which form augen in the strong, chloritic foliation.

Several outcrops of very schistose, locally weathered tonalite (almost phyllonite) west and northwest of Grandys Lake probably represent small, early high strain zones associated with the more penetrative deformation of the north-central high strain zone. They contain red-brown, partly chloritized biotite interlayered with muscovite, profuse accessory apatite, and rare patches of orthoclase, perthite and myrmekite overprinting the plagioclase. The dominant fabric in these zones is the crenulation schistosity, defined by oblate domains of polygonized quartz and the segregation of partly chloritized biotite and muscovite.

The tonalite around the late quartz diorite-megacrystic granite in the northeast corner of the area is hydrothermally altered, and contains secondary muscovite, epidote, local chlorite, allanite, profuse apatite and fibrolite. Plagioclase is finely sericitized and overgrown by muscovite and fibrolite.

Garnetiferous biotite tonalite (Unit 4b)

The garnetiferous biotite tonalite (4b) is a foliated to gneissic granitoid rock with a highly variable garnet content, which encloses abundant mixed metasedimentary and metabasic rocks (2c,b, 1d,e) as xenoliths. The metasedimentary inclusions are commonly garnetiferous, and are difficult to separate from granitoid rock in some exposures. The garnetiferous tonalite passes gradationally into the biotite tonalite (4a) with mafic meta-igneous inclusions.

Unit 4b displays a weak gneissosity or penetrative schistosity is defined by biotite segregation. The fabric is strongly folded or crenulated, and largely transposed into the north-westerly structural trends typical of this zone. The biotite is also crystallized along the crenulation or second schistosity.

The garnetiferous biotite tonalite is composed of andesine, quartz, red-brown biotite, almandine garnet, local microcline, local myrmekite, and very rare, blue-green amphibole. Secondary carbonate, epidote minerals, muscovite, and chlorite also occur locally. Magnetite and zircon are ubiquitous accessory minerals, and pyrite occurs in some places.

The quartz to plagioclase ratio is less than one throughout much of the unit. In the least foliated rocks, large, anhedral grains of weakly deformed quartz embay plagioclase. In very foliated rocks, quartz appears as coarse, polygonized lenses which partly define the crenulation or second foliation, and as tiny, unstrained grains overprinting plagioclase. Andesine is commonly lightly sericitized, and locally displays mottled extinction.

Garnets are generally abundant and vary widely in size. Very small, inclusion-free garnets overprint the biotite in some of the tonalites. Many of the granitoid rocks contain medium to coarse, subhedral garnets with inclusions. They tend to cluster with biotite. In highly strained rocks, skeletal, inclusion-rich garnets are

Plate 41: *Photomicrograph showing quartz (q) and highly altered plagioclase (alt. pg) in tonalite (4b) from the 'metasomatic' part of the north-central high strain zone. MS-80-004. Cross polarized light.*

broken and the fragments strung out along the second foliation. Rare nodules of very fine grained, inclusion-free garnets probably represent partly assimilated xenoliths of the microcrystalline garnet-quartz rock of Unit 2c.

The garnetiferous tonalite and its inclusions are intensely deformed and locally leached in the southwest part of the zone (Figure 2: "metasomatic zone"). The altered tonalite has a quartz to plagioclase ratio commonly exceeding one. Highly sericitized plagioclase is replaced by quartz, and is overprinted by muscovite flakes and rare carbonate patches (Plate 41). Fibrolitic mats occur locally in place of muscovite as a replacement of plagioclase. Acicular epidote crystals align with biotite in some very foliated rocks. Local myrmekite is developed. Biotite in the most highly altered rocks is either leached and fine grained rutile exsolved, or it is partly chloritized. Large, dendritic garnets are particularly common. Disseminated, fine to coarse grained magnetite is concentrated locally.

Garnetiferous tonalite to granodiorite (Unit 4c)

The garnetiferous tonalite to granodiorite (4c) is intimately associated with paragneiss (2a) and subordinate amphibolite (1e). It occurs as numerous sheets or structurally concordant masses which enclose screens of host rocks.

Unit 4c consists of medium grained, gneissic to schistose tonalite, granodiorite, and local granite. The gneissosity reflects the segregation of biotite and muscovite and/or fibrolite, and is generally crenulated or transposed. The overall grain size of the rock decreases with the increasing development of the second foliation. In the northeast part of the Stag Hill high strain zone, the second fabric which transposes the early gneissic fabric is very intense and locally mylonitic. A strong rodding lineation is displayed by hybrid granitoid and metasedimentary rocks at Stag Hill.

Unit 4c generally contains plagioclase, quartz, biotite, almandine garnet, muscovite, local microcline and myrmekite, and sparse, local fibrolite. Secondary chlorite, sericite, and epidote minerals occur in some of the rocks. Zircon, scarce apatite, and sphene and magnetite are ubiquitous accessory minerals. Magnetite and ilmenite occur in the south. Plagioclase (calcic oligoclase to sodic andesine) tends to form porphyroclasts. It occurs as relatively large grains with ragged, corroded boundaries where it constitutes up to 50 per cent of the rock, but as small grains overprinted by both large and small grains of quartz where it is subordinate in proportion to quartz. Quartz grains and grain aggregates display ribbon-like and amoebic outlines in highly deformed rocks. Biotite, intergrown with less abundant flakes of muscovite, is red-brown to olive green in color, and is locally chloritized. Probable platy ilmenite in contact with chloritized biotite is generally rimmed with fuzzy sphene or leucoxene. Garnets are mainly rounded to flattened, but are locally dendritic. Small garnets are inclusion-free, but large garnets commonly contain randomly-arranged inclusions of quartz and plagioclase. Muscovite occurs as ragged porphyroblasts either associated with biotite or overprinting plagioclase, and as matted sericitic intergrowths. Microcline (if present) forms small, clear, interstitial grains or forms large, clear, ragged grains with inclusions of quartz and optically continuous remnants of sericitized plagioclase. Myrmekite lobes embay the microcline. Fibrolite occurs as bundles or sprays overprinting feldspar or radiating from feldspar grain boundaries, and as needles within muscovite.

Near high strain zones, the granitoid rocks are highly retrogressed. Biotite is chloritized, and the garnets are commonly corroded and partly replaced by chlorite. Muscovite enrichment is common.

Pink granite (Unit 4d)

The foliated pink leucogranite occurs in several spatially distinct areas of the Little Codrov Pond belt, and ranges between extremes in microcline to plagioclase ratio and degree of fabric development (or obliteration) even on outcrop scale. Mafic metavolcanic rocks and amphibolite are the main hosts, but marble and impure calcareous metasedimentary rocks host the leucogranite locally.

The leucogranite is generally composed of quartz, plagioclase, microcline, local myrmekite, biotite, local blue-green amphibole, and local muscovite with accessory epidote, apatite, local magnetite, sphene and zircon. The fabric varies from schistose to gneissose, and is composite. Proportions of microcline and plagioclase vary inversely, with the total feldspar content approximately constant. Microcline is clear and nonperthitic, and corrodes or overprints highly sericitized plagioclase. Amphibole rimmed with biotite is rare.

Small pods of quartz syenite and microcline-quartz pegmatite intrude amphibolite (1e) and metagabbro (1b,1c) of the Long Range Mafic-Ultramafic Complex. The quartz syenite is composed of mesoperthite (commonly over 75 modal per cent), quartz (less than 15 modal per cent), plagioclase, myrmekite, chlorite and muscovite. Ferristilpnomelane, magnetite, epidote, zircon, and abundant sphene are accessory minerals. The mesoperthite is occluded with iron oxide, and forms large, fractured, ragged-edged grains embayed by a fine grained mesostasis of alkali feldspar, plagioclase, and myrmekite. Chlorite occurs in matted, polycrystalline patches which are veined with ferristilpnomelane and are associated with fine grained quartz and rare magnetite. Muscovite flakes overprint all minerals. This unit is less intensely foliated than other rocks near the fault.

Relative age and origin

The granitoid rocks of this unit intruded the Long Range Mafic-Ultramafic Complex (1) and the metasedimentary rocks (2) north of the Cape Ray Fault before, and locally during, the early regional deformation and metamorphism. They are intruded by the quartz diorite-megacrystic granite (7) after the formation of the second fabric, and by the megacrystic quartz monzonite (6) either before or after the formation of this fabric. Plugs of pink, perthite-rich granite (10) and mafic and felsic dikes (11) also cut the foliation of the granitoid rocks.

The tonalite (4a) and its mafic inclusions (1c) unconformably underlie the Windsor Point Group (Brown, 1977; Chorlton, 1980b). In the Grandys Lake area, mylonite derived from the tonalitic terrane occurs as clasts in Windsor Point Group volcaniclastic rocks. Fragments of foliated tonalite occur in Windsor Point Group conglomerates in the Port aux Basques area (Brown, 1975, 1977) and in the La Poile River area (Chorlton, 1980b). Devitrified to glassy rhyolite dikes (8) cut the tonalite terrane several kilometres northeast of the bend in Isles aux Morts Brook, and must have been emplaced after the terrane was uplifted and at least partly cooled.

These granitoid rocks show no evidence of derivation by fractional crystallization of more mafic magma, and were probably derived by partial melting during deformation. There is no evidence that any of the present hosts to the granitoid rocks reached metamorphic temperatures and pressures adequate for the onset of either hydrous or anhydrous partial melting much before the emplacement of the granitoid magma, although the veined semipelitic paragneisses (2a) and the garnetiferous tonalite-granodiorite sheets (4c) in the Stag Hill high strain zone may be the result of partial melting *in situ* during deformation and metamorphism. This is not true for the Dinosaur Pond belt. The biotite tonalite (4a), at least, was generated at deeper tectonic levels than represented by the terrane now exposed. A tentative model for the emplacement of tonalite is suggested in Figure 6.

Postemplacement, polyphase regional deformation under middle to upper amphibolite facies metamorphic conditions has played a significant role in the present mineralogical composition and texture of the sillimanite-bearing, garnetiferous granitoid rocks (4b,c). The biotite tonalite (4a) was recrystallized during deformation under lower amphibolite or upper greenschist facies conditions at most. It is suggested here that the transition from biotite tonalite (4a) to garnetiferous biotite tonalite (4b) corresponds to an increase in postemplacement regional strain and metamorphic grade, and also to contamination by metasedimentary inclusions (2c), some of which consisted of highly ferrugenous and aluminous claystone and mudstone. The siting of a major component of early thrusting above the level of the mafic metaigneous/ metasedimentary rock interface in the north-central part of the area may be responsible for the structural and metamorphic contrast (Figure 6, and cross-sections accompanying map).

Large volumes of trondhjemite and tonalite in some Archean gray gneiss terranes have been interpreted as the results of partial melting of metamorphosed mafic rocks (e.g. Arth and Hanson, 1972; Hanson and Goldich, 1972; Barker and Arth, 1976; Collerson and Fryer, 1978; Arth, 1979; Gower, in preparation). Layered metagabbros (1b) underneath the massive metagabbro and metadiabase (1c), that were uplifted and locally hydrated under upper amphibolite facies temperatures at the base of a thrust sheet, are possible mafic

sources. In this context, the timing of the early granulite facies metamorphism of the layered metagabbros relative to the regional tectonic history might be significant. In addition, lower Paleozoic trondhjemite and quartz diorite suites associated with metamorphosed mafic rocks in Newfoundland, the Little Port Complex and the Twillingate Trondhjemite, have tentatively been interpreted as the results of partial fusion of metamorphosed oceanic crust (Malpas, 1979; Payne and Strong, 1979), either in an oceanic island arc environment (Williams and Payne, 1975; Payne and Strong, 1979), or in an oceanic fracture environment (Karson and Dewey, 1978; for the Little Port Complex only). Both interpretations imply the involvement of plate tectonic processes; in this context also, the timing of magma emplacement and deformation is vitally important.

The pink leucogranite (4d) is sited primarily in amphibolitic hosts along major high strain zones, and may have been derived by partial melting with unlimited access to volatiles and alkalis along the shear zone during its generation, emplacement, and subsequent deformation and metamorphic recrystallization. Consequently, alkali metasomatism could be an important factor governing its present composition. In contrast, the mafic-hosted biotite tonalite (4a), which was not emplaced into a major shear zone, probably acted as a relatively closed system with respect to volatiles and alkali elements during emplacement and subsequent metamorphism.

3.3. Synmetamorphic granitoid rocks, pegmatites, and veins (Unit 5)

Unit 5 includes medium grained, equigranular granitoid rocks which were intruded into metasedimentary rocks and amphibolites of the modified Bay du Nord Group (3) between the first and second regional deformations. The unit can be described in terms of two mutually gradational end members, Rose Blanche (5a) and Port aux Basques (5b) phases, which can be broadly correlated with the Rose Blanche and Port aux Basques Granites of Brown (1975) (see Appendix I). The Rose Blanche phase is exposed as outcrops of massive, foliated granitoid rocks with local metasedimentary migmatite screens; it grades into a terrane where partly migmatitic metasedimentary gneiss and schist as well as amphibolite are profusely intruded by gneissic to schistose granitoid sheets, most of which can be assigned to the Port aux Basques phase.

Gradational boundaries with the 'Bay du Nord Group' are indicated on the map, positioned on the basis of observed proportions of granitoid to host rocks and, to a limited degree, interpretations from air photographs.

Pegmatites as well as related quartz and kyanite-quartz veins are located mainly where the granitoid rocks and their 'Bay du Nord' hosts were most highly deformed.

The Rose Blanche phase (5a) is characterized by medium grained schistose tonalite to granodiorite with minor granite which are gradational. A penetrative schistosity, generally conjugate in aspect, is defined in thin section by flattened quartz domains, weakly porphyroclastic plagioclase, and weakly by micas. In some rocks, one of the conjugate schistosities is developed preferentially.

The Rose Blanche phase is composed of 40-60 modal per cent plagioclase, 25-35 modal per cent quartz, 5-15 modal per cent olive green biotite, and minor muscovite. Alkali feldspar and minor myrmekite occur locally as principal constituents. Accessory minerals include zircon, magnetite, apatite, epidote, and local sphene, allanite, fibrolite and garnet. Plagioclase (An_{20}- An_{40}) occurs as zoned, subhedral laths which form

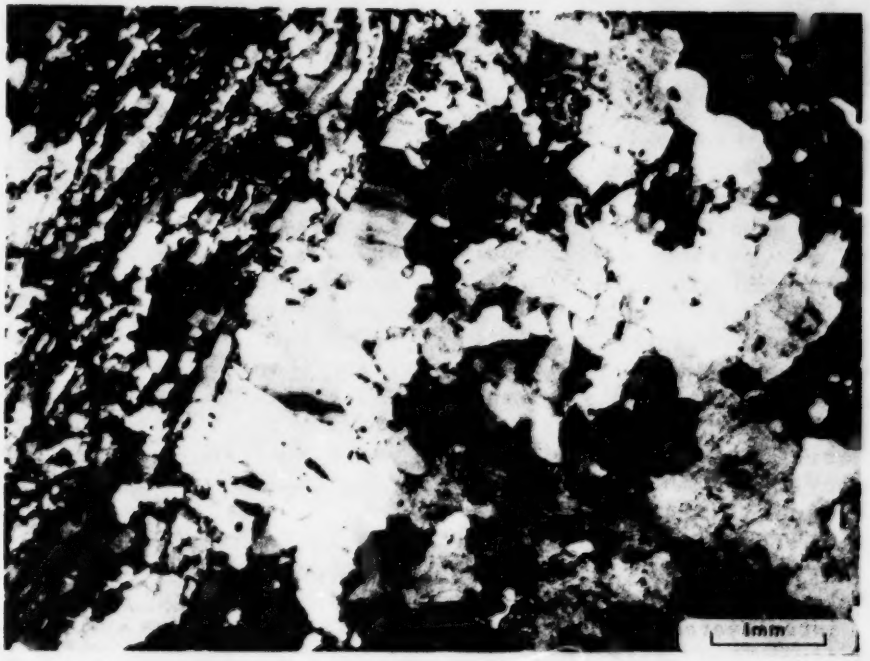


Plate 42: *Gneissic granodiorite (5a) west of Northwest Brook, showing mica-rich layer (LHS) and quartzofeldspathic band (RHS). 80-LC-306. Cross polarized light.*

porphyroclasts in relatively deformed rocks. Quartz occurs as polygonized grains with irregular to sutured domain boundaries, generally interstitial to plagioclase. Large grains of alkali feldspar commonly consist of untwinned orthoclase or microcline hair perthite (less than 5 per cent exsolved plagioclase) rimmed with gridiron-twinned microcline, some with sericitized plagioclase inclusions. Myrmekite, if present, generally embays the microcline. Mica flakes generally occupy and slightly embay grain boundaries in the quartzofeldspathic assemblage. Minor fibrolite is developed around the micas in some of the rocks and may also overprint leucocratic domains, especially near the Cape Ray Fault. Allanite and sphene are unusually abundant in some of the tonalitic rocks in the northeast.

Gneissically-banded tonalite to granodiorite (5a) is characterized by sharply to gradationally bounded, alternating melanocratic and leucocratic layers (Plate 42). The melanocratic bands in the well segregated gneisses are largely composed of olive brown to red-brown biotite and muscovite. Accessory opaque minerals, zircon, apatite and rare euhedral garnet are concentrated in the melanocratic bands. The leucocratic bands are composed mainly of unzoned to weakly zoned oligoclase and strained quartz. Granitoid rocks near the Cape Ray Fault locally contain augen of feldspar and abundant coarse muscovite. The augen in most rocks consist of coarse to medium grained, corroded to highly embayed crystals of zoned plagioclase (oligoclase-andesine). However, large myrmekite-rimmed porphyroblasts of microcline, and smaller porphyroclasts of hair perthite, are locally abundant. The microcline porphyroblasts consist of hair perthite with non-perthitic microcline rims. These rocks are also characterized by very coarse, red-brown biotite with abundant zircon and coarse

apatite inclusions. Very coarse muscovite buttons occur in microcline-free rocks.

The Port aux Basques phase (5b) consists of pink to white, medium grained, largely equigranular granitoid rock which varies in composition from tonalite to true granite. Samples of the entire compositional range can commonly be obtained from a single outcrop.

A very strong, crenulated to tightly folded foliation is due to flattened quartz domains, dimensional preferred orientation of feldspar grains, and preferred orientation of biotite, muscovite, and amphibole. Biotite and amphibole are concentrated along the crenulation schistosity in many rocks. A prominent segregation gneissosity is developed where the granitoid rocks are intricately interlayered and deformed with metasedimentary gneisses. The gneissosity is folded in many outcrops, but is merely transposed parallel to the regional northeast trending structural grain in others.

The Port aux Basques phase is composed of inequigranular intergrowths of 20-60 modal per cent plagioclase, 30-40 modal per cent quartz, 2-15 modal per cent dark brown biotite, and local alkali feldspar, myrmekite, chloritized biotite, muscovite, and blue-green amphibole. Zircon, apatite, epidote, allanite, and local magnetite, sphene, garnet and fibrolite are accessory minerals. Plagioclase consists mainly of clear, unzoned, corroded anhedra of oligoclase-andesine. Rare grains with oscillatory zoning occur locally. Quartz forms a strained and annealed network which engulfs and embays plagioclase. Fine grained quartz occurs along quartzofeldspathic grain boundaries, and also as small, rounded grains over-printing plagioclase grains. Alkali feldspar (if present) occurs both as interstitial microcline and as domains of hair perthite with irregular rims of nonperthitic, gridiron-twinned micro-cline. The partly perthitic domains may represent fragments of larger crystals that were rotated slightly during defor-mation; nonperthitic, twinned microcline rims are an annealing phase. Myrmekite, up to 5 modal per cent in the presence of microcline, either embays microcline or forms part of the leucocratic inter-growth. The amphibole, where present, exhibits intense blue-green pleochroism, and has a negative 2V, varying from 50 degrees to considerably less in differ-ent specimens. On the basis of optical properties, it could be either blue-green hornblende or ferrohastingsite. The grains are anhedral to subhedral and prismatic in habit, and many poikiliti-cally enclose grains of quartz, plagic-clase, and biotite (Plate 43).

The pegmatites range from several centimetres to over a metre thick, and were generated along and across foliation planes. They are composed mainly of quartz, feldspar, muscovite and biotite, but some of the thicker pegmatites contain garnet, tourmaline and apatite. A pegmatite in southwest Grandys Brook contains kyanite as well as garnet and tourmaline. Intensely deformed, pink weathering pegmatite occurs as layers in the pink weathering, gneissic granitoid rock and 'Bay du Nord' screens exposed along Rose Blanche Brook (Plate 44).

Thick bands of blue or green, color zoned kyanite and quartz exposed on the hillside overlooking Grandys Brook are similar in grain size to the pegmatites. Mylonitized granitoid sheets exposed along strike in the falls on Grandys Brook consist of quartz, muscovite, kyanite, and sillimanite.

Apparently barren, boudinaged quartz veins several metres thick occur along the dominant northeast trending foliation in the same area.

Relative age and origin

The equigranular, synkinematic granitoid rocks of this unit were emplaced into the 'Bay du Nord Group'

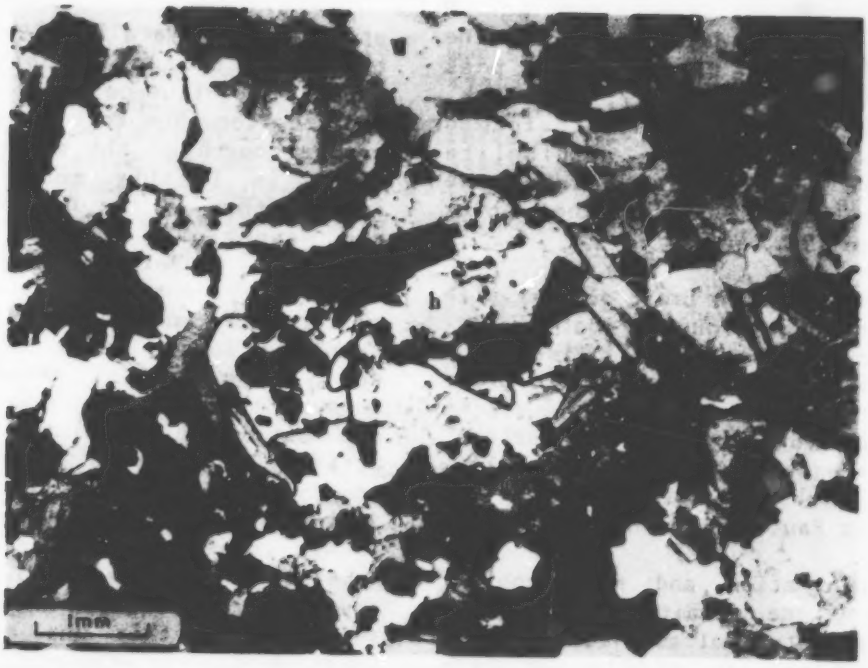


Plate 43: *Photomicrograph of Port aux Basques phase (5b) showing highly deformed and recrystallized nature of the granitic intergrowth, with poikilitic blue-green amphibole (h) outlined in the centre of the photograph. 79-LC-256. Cross polarized light.*

Plate 44: *Intensely deformed granitoid rocks with deformed pegmatitic layers and possible screens of metasedimentary schist, Rose Blanche Brook.*

after the earliest deformation and the attainment of the metamorphic peak (Brown, 1972, 1976a, 1977; Chorlton, 1980b). They were intensely deformed under the prevailing, amphibolite metamorphic conditions before the emplacement of the fine grained, pink leucogranite (9).

The granite is in fault contact with the Windsor Point Group in most places, but evidence in the La Poile River area suggests that it was deformed (D_2) prior to the eruption of the Windsor Point Group mafic volcanic rocks (Chorlton, 1980b). Its age relative to the tonalite (4), with which it is in contact along the Cape Ray Fault, is unknown.

The deformation and metamorphism, during which the granitoid rocks were emplaced, affected volcanic rocks to the southeast dated as middle or late Ordovician (446±20 and 449±20 Ma; Chorlton, Dallmeyer, and Odom, in preparation), and predated the latest Early Devonian or earliest Middle Devonian Windsor Point Group. It is cut by the La Poile batholith (432±20 Ma; Chorlton et al., in preparation) east of the map area. Thus, the granitoid rocks are probably Silurian in age.

The Rose Blanche and Port aux Basques phases were emplaced while metamorphic conditions were sufficient to bring about partial melting in the hydrous metasedimentary and amphibolitic rocks that they intrude. Therefore partial melting of the modified 'Bay du Nord Group' is considered the most likely origin for these phases. The fairly thick sheets or bodies of granitoid rock suggest that some of the magma was generated and collected slightly deeper in the metamorphic pile. The transition from the Rose Blanche phase (5a) to the Port aux Basques phase (5b) may reflect an increase in the proportion of amphibolitic to metasedimentary parent.

In addition, the occurrence of the Port aux Basques phase within 5 km of the Cape Ray Fault, and its more highly strained, recrystallized nature suggest that its tectonic position was an important influence on postemplacement modification. The Port aux Basques phase exposed south of the map area near the coast is locally much more coarse grained than in the Grandys Lake area, and contains numerous pegmatitic veinlets. Petrographic textures exhibited by most samples from this map area and by several samples collected near the Rose Blanche highway to the south suggest that relatively large feldspar grains were fragmented during deformation in many rocks. Metasomatic activity in a broad belt southeast of the fault chemically altered the granite during deformation and recrytallization. It was probably responsible for several generations of alkali feldspar, locally abundant microcline, and myrmekite in samples from this map area and also local albite in samples to the south (Dingwell, 1980). The movement of Na, K, Ca and mobile trace elements in the Port aux Basques phase southwest of the map area has been demonstrated by Dingwell (1980) and Dingwell and Strong (1981). Mineralogically and texturally similar granitoid rock, hosted mainly by amphibolite, is exposed near the Cape Ray Fault in the Peter Snout area (Unit 8c of Chorlton, 1980a). A parallel can be drawn between the mineralogical variation, texture, and tectonic position of the Port aux Basques phase and those of the foliated, pink granite (4d) in the northwest part of the Grandys Lake area.

It is suggested here that the quartz-kyanite veins and the aluminosilicate-bearing, felsic mylonite in the southwest formed by hydrothermal leaching of pegmatites and granitoid sheets, respectively. Similar processes have been described by Gresens (1971) for pegmatite- and quartz-kyanite deposits in northern New Mexico, and by Vernon (1979) for the production of late sillimanite in some high grade gneisses. The circulation of hydrothermal fluids required for this process may be related to hydrothermal activity associated with the Cape Ray Fault zone. Pressure was

adequate for the production of kyanite in the southwest, and either the temperature barely adequate during early deformation for the local production of fibrolitic sillimanite or during late uplift pressure suddenly decreased to allow for fibrolite production. Sillimanite (largely fibrolite), rather than kyanite, is the predominant aluminosilicate polymorph in foliated granitoid rocks and metasedimentary schists in the eastern and central parts of the map area, probably signifying slightly higher temperatures.

4. ROCKS EMPLACED AFTER THE SYNMETAMORPHIC GRANITOID ROCKS BUT PRIOR TO THE FORMATION OF THE CAPE RAY FAULT, AND ARE TENTATIVELY ASSIGNED TO STAGE 2B

4.1 Introduction

Two plutons north of the Cape Ray Fault, one composed of megacrystic quartz monzonite (6) and the the other of quartz diorite to megacrystic granite (7), were emplaced after the tonalite and other granitoid rocks (4). The megacrystic quartz monzonite (6) is intensely deformed with its hosts by late deformation along the southeastern boundary of the Stag Hill high strain zone, therefore obliterating any chance of determining whether it postdated the early foliations of its hosts. However, the quartz diorite-megacrystic granite (7) postdated the foliation developed in the tonalite of the Dinosaur Pond belt and predated the Cape Ray Fault.

4.2 Deformed, megacrystic quartz monzonite (Unit 6)

Unit 6 consists of inhomogeneously deformed, coarse grained, megacrystic quartz monzonite, characterized by abundant crystals of plagioclase and microcline which form augen in the sheared granitoid matrix. It is relatively uniform in overall composition.

This unit is exposed in the Grandys Lake area as two main intrusive bodies. The larger encloses rafts of metagabbro (1c), and screens of equigranular granitoid rock (4). The smaller body intrudes the massive metagabbro and metadiabase (1c) and projects dikes or apophyses into the mafic rocks (1) and the tonalite (4a). Tightly folded dikes of coarse grained, porphyritic quartz monzonite cut the highly deformed, undivided amphibolite (1e) and tonalite (4a) exposed between the two main intrusions.

The quartz monzonite (5) contains 35 per cent megacrysts of plagioclase and microcline in a fine grained matrix of quartz, olive green biotite, coarse epidote, and minor local microcline or plagioclase. Accessory coarse sphene is exceptionally abundant, and magnetite is less abundant. Secondary muscovite and minor interstitial chlorite occur locally. Oligoclase megacrysts predominate in some samples, and microcline in others. Five to ten per cent dark minerals are visible in hand specimen. Patches of nonporphyritic to megacryst-poor, coarse to medium grained quartz monzonite or granodiorite occur near the margins of the intrusions in a few places. Aplite and pegmatite is exposed around both intrusions.

The quartz monzonite is intensely, but inhomogeneously, deformed. Megacrysts are flattened to lenticular augen, and some crystals are fractured and strung out in an anastomosing foliation defined by stringers of very fine grained ferromagnesian minerals and recrystallized quartzofeldspathic matrix. The large plagioclase crystals are bent, fractured, and commonly kink-banded. Microcline forms larger, ragged-edged augen, and consists largely of string perthite (less than 5 per cent exsolved plagioclase) in which gridiron twinning is developed to a variable degree. Grain margins are locally embayed by myrmekite lobes, and large grains are crisscrossed by fractures lined with very fine grained quartz, epidote, and biotite. Smaller, optically-disoriented microcline grains occur in the elongated corners of the microcline augen. Muscovite, present mainly in the most highly deformed rocks, either forms small flakes which overprint plagioclase along crystallographic planes or occurs as coarse buttons which form augen in a biotite-depleted mylonitic foliation defined by quartz ribbons.

Relative age

The megacrystic quartz monzonite (6) intrudes the massive metagabbro and metadiabase (1c) and the intrusive tonalite (4a), undivided amphibolite

(1e), and gneissic granitoid rocks (4c). As with other large, megacrystic quartz monzonite bodies in the region, confusion results because the main body is sited along a tectonic boundary; here, it obscures part of the southeast boundary of the Stag Hill high strain zone, which underwent movement in Carboniferous time (Figure 3b).

4.3 Quartz diorite to megacrystic granite (Unit 7)

Unit 7 is an intermediate to felsic intrusion characterized by widely varying composition, randomly oriented hornblende and biotite. It occupies parts of the Dinosaur Pond belt and the adjacent La Poile River area (Unit 17 of Chorlton, 1980b). Many screens of the tonalite and its mafic meta-igneous inclusions are enclosed in the body, and patches of diorite occur away from the main pluton, making the precise boundary difficult to define.

The intrusion varies from medium grained quartz diorite (7a), the predominant phase, to megacrystic granite or quartz monzonite (7b). Quartz diorite grades abruptly or more gradually into orthoclase (and plagioclase) megacrystic granite or quartz monzonite. Pink aplite (7c) cuts some of the highly altered tonalite/amphibolite screens, and pegmatite was observed locally.

The quartz diorite has freshly fractured surfaces which show about 30 per cent randomly oriented dark green hornblende and dark brown biotite overprinted by white plagioclase laths, and make it distinctive from the older rocks (4,1). The megacrystic granite or quartz monzonite is characterized by a variable abundance of rectangular, pink alkali feldspar porphyroblasts which overprint the medium grained quartz diorite matrix. The porphyritic quartz monzonite contains zoned plagioclase phenocrysts and white to pink weathering orthoclase megacrysts in a medium grained granodiorite or quartz diorite matrix.

The quartz diorite (7a) and the megacrystic granite to quartz monzonite (7b) are essentially composed of up to 35 per cent plagioclase, amphibole, biotite, and quartz, with locally abundant alkali feldspar. Epidote, chlorite, and coarse sericite are locally present as late magmatic or secondary phases. Carbonate patches may also be present in some of the highly sheared rocks. Accessory minerals include sphene, zircon, epidote, magnetite, pyrite, and exceptionally abundant apatite.

Plagioclase forms zoned, subhedral laths with cores of calcic andesine and sharply bounded rims of sodic andesine. Phenocrysts of plagioclase are rare in the quartz diorite, but are relatively abundant in the quartz monzonite. Plagioclase varies from totally unaltered to patchily or completely sericitized. Saussuritization of the more calcic cores occurs mainly in the highly sheared rocks to the south.

Alkali feldspar, if present, is largely perthitic orthoclase (about 10 per cent exsolved albite) which is converted to finely gridiron-twinned microcline along grain fractures and rims. The perthitic orthoclase is distinct from other perthites found in the area in that the domains of exsolved albite are very fine, forming short, diffusely-bounded stringlets which generally wrap around cleavage intersections. It forms large, clear, ragged-edged laths (Plate 45) which enclose small, rectangular inclusions of highly sericitized plagioclase and fewer inclusions of biotite, amphibole, epidote, and chlorite. In the presence of orthoclase, plagioclase is commonly totally sericitized (Plate 45). Myrmekite is not common, occurring as lobes along the alkali feldspar grain margins in some rocks.

Quartz occurs in sporadic patches interstitial to, but weakly embaying, plagioclase. Polygonization and irregular curved deformation lamellae are locally developed.

Plate 45: *Photomicrograph showing orthoclase-microcline (or) porphyroblast overprinting highly altered plagioclase (pg), quartz (q), chloritized biotite (chl, bi) and hornblende (h) of quartz dioritic matrix. 80-LC-366. Cross polarized light.*

The amphibole displays a normal blue-green pleochroic scheme, has a low $2V_x$, and is commonly twinned. It may be either true hornblende or hastingsite.

Khaki brown biotite and amphibole in reciprocal proportion form interstitial clusters. Together they constitute about 40 per cent of the quartz diorite and less in the other rock types. Both biotite and amphibole enclose unusually abundant apatite crystals. Biotite is locally chloritized. In some of the more altered rocks, large prismatic grains of deeply pleochroic, yellow epidote, some with cores of allanite, cluster with ferromagnesian clots, and biotite is largely altered to chlorite with lenticles of sphene along old cleavage traces.

The aplite (7c) is composed of a fine grained, hypidiomorphic intergrowth of alkali feldspar, oligoclase, and quartz in subequal proportions, with minor amounts of myrmekite, biotite, chloritized biotite, and muscovite. Zircon, opaque minerals, sphene, and minor apatite are accessory minerals which are generally enclosed in biotite or chlorite. Alkali feldspar consists largely of orthoclase perthite similar in texture and composition to that of the megacrystic quartz monzonite. Microcline rims some of the grains, and occurs in fractured or deformed areas within perthite grains and at multiple grain junctions. Oligoclase occurs as elongate laths which are generally partly altered to coarse sericite or muscovite flakes. Chloritized biotite contains sphene and epidote, but the other accessory minerals are very sparse. Rare myrmekite occurs as rounded lobes, and as fringes along feldspar grain boundaries.

The intrusion is more highly fractured and altered in the east and southeast than it is in the northwest.

Plate 46: *Photomicrograph of highly altered garnetiferous tonalite (4b?) showing alteration of plagioclase (alt. pg), leached biotite, and fragments of relict garnet (gt). DD-80-200: Plane polarized light.*

It is largely unfoliated, but shearing is evident near the Cape Ray Fault. Several sheared outcrops of the granite or quartz monzonite within the Cape Ray Fault zone just east of the map area are leached of almost all mafic constituents.

Contact effects, such as alteration of feldspars and chloritization of biotite, occur in the tonalite complex at the boundary and may extend for an uncertain distance to the west. The affected rocks characteristically have a highly weathered appearance. Muscovite is commonly oriented along cleavages, and as dense intergrowths of matted acicular flakes. The mats resemble retrogressed fibrolite knots, commonly preserved without retrogression in tonalitic screens. One sample of garnetiferous gneiss (4b or 2c) from very near the mapped contact shows a similar effect (Plate 46): the sample contains coarse, subrounded garnets concentrated in coarse, biotite-rich (now rutilated chlorite) gneissic bands which are cross-cut at a high angle by bands of matted sericite or muscovite. Some patches of sericite have square cross-sections reminiscent of prismatic sillimanite.

It is uncertain whether the contact aureole connects with, or is the cause of, some of the alteration in southeastern 'metasomatic' part of the north-central high strain zone. The exposure of sporadic patches of the intrusive quartz diorite away from the western boundary of the main surface exposures of the body may mean that the intrusion is either continuous in the subsurface or present as smaller bodies for some distance to the west. It is therefore difficult at present to assess whether such a width of altered rocks could reasonably be related to this intrusion.

Relative age and origin

The quartz diorite to megacrystic granite cuts the deformed tonalitic rocks (4a, b) and their inclusions (1e, 2c) after the formation of the early penetrative schistosity or gneissosity of these rocks. The body is itself cut by mafic and felsic dikes (11a, b)) in this map area, and by a plug of pink, perthite-rich leucogranite (10a,b of this report) and its fine grained dikes (10c) in the adjacent La Poile River area. Both sets of dikes are straight-sided and very fine grained. The intrusion must have cooled, and possibly been uplifted with its host terrane before the emplacement of the dikes. However, the felsic dikes (11b) in this corner of the Grandys Lake area have apparently been affected by hydrothermal alteration, suggesting that hydrothermal activity, related to either the fault system or the intrusion, was still active when they were emplaced.

There is no direct field evidence to indicate the age of this intrusion relative to the deposition of the Windsor Point Group. A strikingly similar pluton in the King George IV area is overlain unconformably by the Windsor Point Group (Kean, 1983). In previous work, the pluton exposed in this and the adjacent La Poile River area was arbitrarily assumed to be younger than the Windsor Point Group (Chorlton, 1980b), probably in error. It is suggested here that the quartz diorite-megacrystic granite postdates the early penetrative deformation of the host rocks, but predates final uplift of the terrane north of the Cape Ray Fault and the eruption and deposition of the Windsor Point Group along the fault.

Sheared and leached apophyses of the pluton around Garia Brook in the Cape Ray Fault zone were thought to intrude a late to post-tectonic quartz gabbro/diabase in the La Poile River area (Unit 14 of Chorlton, 1980b). The mafic host rocks, like the apophyses, were sheared and retrogressed by the late activity in the fault zone. However, the prevalence of older mafic meta-igneous rocks north of the Cape Ray Fault has only recently been recognized (e.g. Chorlton, 1980c, 1981), and it is now suggested that most of the mafic rocks intruded by Unit 7 in the fault zone are actually amphibolites derived from the Long Range Mafic-Ultramafic Complex. Clinopyroxene-bearing quartz monzodiorite of Unit 7, exposed locally in the northwest corner of the La Poile River area, is somewhat similar, except for exceptionally abundant apatite, to clinopyroxene-bearing quartz gabbro phases exposed on brooks further east, e.g. Nitty Gritty Brook, Morg Keepings Brook, so that the intrusions might be related. The major distinctions between the quartz diorite phase of Unit 7 and the quartz gabbro/diabase in the La Poile River area are: (i) the local presence of brown rather than green igneous hornblende or amphibole, coarse crystals of sphene, and abundance of magnetite in the quartz gabbro (Unit 14 of Chorlton, 1980b); (ii) the exceptional abundance of apatite in Unit 7; and (iii) the gradation of Unit 14 of Chorlton (1980b) from medium grained, subophitic gabbro to relatively fine grained diabase. Variations could actually be reflections of compositional zonation, late magmatic hydrothermal activity, or the contrasting levels of emplacement presently exposed rather than separate origin. The quartz diorite to megacrystic granite intrusion (7) is considered to have been emplaced during the same tectonic interval as the quartz gabbro/diabase in the La Poile River area, but not necessarily related to the same magma chamber.

Without petrochemical study, little can be said about the affinities of the quartz diorite to the megacrystic granite intrusion, but several features are noteworthy. First, the ubiquitous presence of small, partly assimilated amphibolite xenoliths may, in part, reflect residuum from the source terrane. Secondly, the intense sericitic alteration of plagioclase, and possibly

the chloritization of biotite, apparently accompanies the production of clear orthoclase megacrysts in the quartz diorite, producing the megacrystic granite, alteration reminiscent of the deepseated potassic zone of a magmatic porphyry model (Lowell and Guilbert, 1970). Finally, the extreme leaching of the intrusion within the Cape Ray Fault zone suggests that hydrothermal circulation was active along the Cape Ray Fault zone, possibly while the pneumatolitic system was still active or the intrusion still hot (equivalent effects were not noticed in the mafic hosts). There may be potential for granitoid-related porphyry mineralization around the pluton (cf. Hollister et al., 1974). A possible connection between the system and the altered rocks of the north-central high strain zone deserves investigation. Was the intrusion emplaced into an already active hydrothermal system associated with early shear zones and faults, or did the hydrothermal system result solely from emplacement, or both?

5. ROCKS ASSOCIATED WITH THE DEVELOPMENT OF THE CAPE RAY FAULT, AND BELONG TO STAGE 3

5.1 Introduction

The Windsor Point Group (8), of Emsian-Eifelian age, is the only unit intimately associated with the Cape Ray Fault and its development. Volcanic rocks of the Windsor Point Group are strongly bimodal, and the sedimentary rocks were deposited in a fluviatile environment (Chandler, 198?).

5.2 Windsor Point Group (Unit 8)

The Windsor Point Group (Brown, 1975, 1976a, 1977) is an assemblage of bimodal volcanic, volcaniclastic, and sedimentary rocks which were erupted and deposited along the trace of the Cape Ray Fault, exposed from the southwest tip of Newfoundland (Brown, 1975) for at least 125 km inland to King George IV Lake (Kean and Jayasinghe, 1981). Several small subvolcanic granite pods (or rhyolite domes) are coeval with the extrusive volcanic rocks and should be included in the group. Two such pods, the Nitty Gritty Brook Granite (Chorlton, 1980b) and the Windowglass Hill Granite (Bucknell et al., 1980), are exposed in the adjacent La Poile River and Rose Blanche areas, respectively. The informally named Billiards Brook formation of the La Poile River area (Chorlton, 1979, 1980b) is correlated with, and now included in, this group (see Appendix I).

The group is represented in the map area by felsic (8a) and mafic (8b) metavolcanic rocks, and largely volcaniclastic metasedimentary rocks in close association.

Felsic metavolcanic and related volcaniclastic rocks (8a) include rhyolite porphyry, aphyric rhyolite or rhyolite tuff, flowbanded rhyolite, rhyolite breccia, ash-flow tuff, quartz crystal tuff, and other associated volcaniclastic rocks, including minor well bedded siliceous tuff or siltstone and polymictic volcanic conglomerate.

The rhyolite porphyry has rounded phenocrysts of polygonized quartz and, less commonly, altered alkali feldspar. Rhyolite breccia in the southwest corner of the area contains largely angular, lapilli size clasts of aphanitic and flowbanded rhyolite, and broken crystals. Breccia in the northwest part of the wedge is highly deformed, and may be partly tectonic in origin. It contains boulder-size blocks of rhyolite, quartz porphyry, and probably some of the neighbouring tonalite (4). Tuffisite dikes, possibly related to combined fault and volcanic activity, occur along the banding of siliceous mylonite derived from the tonalite complex (4a, 1c) in Isles aux Morts Brook. The mylonite and pink felsite (either 8a or Windowglass Hill microgranite) occur as unsorted, angular fragments in volcaniclastic rocks associated with brecciated felsic and mafic flows exposed in the brook near the tuffisite. Brecciated rocks and fault gouge locally contain fluorite and adundant quartz stringers.

A prominent rhyolite band along the southern contact of the late leucogranite plug (10) northeast of the bend in Isles aux Morts Brook is intensely silicified, and locally incorporated in fault gouge. Ash-flow tuff, best exposed several kilometres northeast of the headwaters of Isles aux Morts Brook, contains agglomeratic fragments of glassy and devitrified rhyolite in a siliceous matrix, and is closely associated with quartz crystal tuff and siliceous siltstone. The siliceous siltstone weathers white; differentially weathered bedded units range from several millimetres to 15 cm in thickness. Conglomeratic rocks that occur toward the northeastern point of the wedge are less well exposed, and contain a mixture of subvolcanic granite (Windowglass Hill?), rhyolite, metasedimentary rock, and foliated tonalite. Minor graphitic slate and chloritic schist occur as interbeds. The

glassy rhyolite dikes contains globular spherulites where not intensely sericitized. It displays a strong rodding lineation, probably a deformational effect of activity on the Cape Ray Fault.

Mafic volcanic and related rocks (8b) include mafic flows and/or dikes, and mafic tuffs. Mafic flows (8b) are largely composed of actinolite, albite, quartz, epidote minerals, and magnetite. Actinolite occurs as deeply pleochroic (Z = blue-green, Y = green, X = pale green), fibrous sheafs, which only locally lie parallel to the schistosity. The leucocratic minerals are very fine grained. Tiny, poorly formed plagioclase phenocrysts are present in some of the basalts. Carbonate- and chlorite-filled vesicles are locally recognizable. Magnetite is finely disseminated, and is generally concentrated along foliation planes. Minor secondary chlorite was observed locally. Fine grained mafic tuffs are interlayered with brecciated felsic volcanic rocks. They contain detrital quartz and muscovite or sericitized patches, relatively coarse grained opaque and epidote minerals, chlorite, and abundant patches of carbonate in addition to the above assemblage. Chlorite schists along the south side of the belt contain abundant carbonate, and are believed to represent mafic volcaniclastic rocks.

The Windsor Point Group is highly deformed within the Cape Ray Fault. A weak to strong planar fabric is commonly chevron or kink folded, with an associated crenulation cleavage in many exposures. Foliations in the Windsor Point Group are statistically indistinguishable from the fabrics which affect rocks of Units 1,3,4, and 5 on either side of the Cape Ray Fault zone where the group was deposited (Wilton, 1981). Therefore, intensely deformed mafic volcanic rocks and associated chloritic schists may be difficult to distinguish structurally as well as lithologically from the older mylonitized amphibolite of either the modified 'Bay du Nord Group' (3) or the mafic meta-igneous rocks of Unit 1. Along the north side of the belt, foliated tonalite with porphyroclasts of quartz, forming augen in the cataclastic foliation, may easily be confused with quartz porphyry.

The Windsor Point Group was metamorphosed to greenschist facies in this area. Greenschist facies mineral assemblages apparently crystallized before, and possibly during, the formation of the penetrative foliation displayed by many of the rocks.

Relative age and origin

The Windsor Point Group unconformably overlies the deformed tonalite (4a) and included mafic meta-igneous rocks (1c,e) north of the Cape Ray Fault. Fragments of both units occur as clasts in Windsor Point Group conglomerates in the Port aux Basques area (Brown, 1975, 1977), and trondhjemite clasts belonging to the tonalite complex were observed in conglomerates in the La Poile River area (Chorlton, 1980b). Siliceous mylonite derived from the tonalite occurs as clasts in volcaniclastic rocks (8a) exposed in Isle aux Morts Brook. The aphyric rhyolite dike cuts the tonalite (4a) and metagabbro (1c), and is deformed by late activity on the Cape Ray Fault.

The relationship of the perthite-rich granite (10) is obscured by the Cape Ray Fault. However, since a projection of the granite cuts the Windsor Point volcaniclastic rocks, the granite is considered to have been emplaced after the deposition of the volcanic and sedimentary assemblage.

The Windsor Point Group is younger than both the modified 'Bay du Nord Group' (3) and the synmetamorphic granitoid rocks (5), and postdates the D_2 foliation in part (Chorlton, 1980b). Plant fossils (*Drepanophycus gaspianus, Taeniocrada, Psilophyton, Trimerophyton* (tentative), and *Pertica*) recovered from

sedimentary strata in Billiards Brook in the La Poile River area (110/16) indicate a latest Early Devonian to earliest Middle Devonian age for the group (W.R.Forbes, personal communication, 1981). The 'Bay du Nord Group' and synmetamorphic granitoid rocks are reversely faulted against the Windsor Point Group along Cape Ray Fault (#2) (Figure 7).

An intracratonic wrench fault model setting for the generation and deposition of the Windsor Point Group is worthy of consideration.

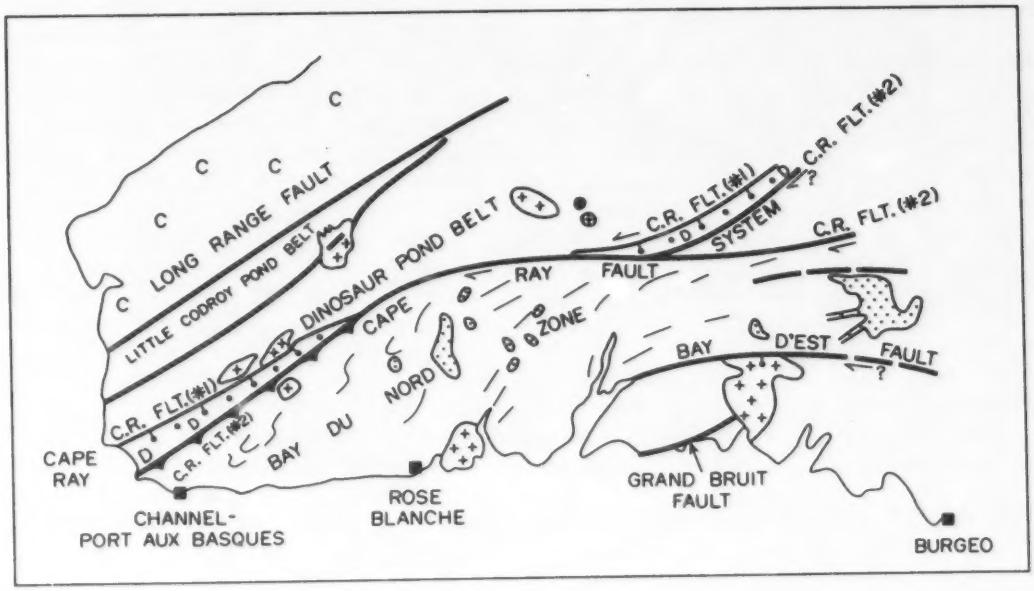


FIGURE 7: *Distribution of late leucogranite plutons, Windsor Point Group, Carboniferous sedimentary basin, and major reverse, block and wrench faults.*

EXPLANATION

Two-feldspar (subsolvus) leucogranite

Perthite-rich (trans-solvus) leucogranite

D D D *Windsor Point Group*

C *Carboniferous sedimentary rocks*

Early to late structural trends (s-planes)

Fault

High angle thrust fault, triangles on overthrust side

Wrench fault, relative movement indicated

Wrench fault with block fault movement and unconformity

6. ROCKS EMPLACED AFTER THE EARLY REGIONAL DEFORMATION AND ARE ASSIGNED TO STAGE 4

6.1 Introduction

Fine grained, two-feldspar leucogranite (9), perthite-rich leucogranite plutons (10), and mafic and felsic dikes (11) truncate the most intense stages of penetrative regional deformation. Since the age of the early tectonic events may differ significantly across the Cape Ray Fault, the maximum age of the late intrusive rocks may accordingly differ on either side of the fault. Both the perthite-rich leucogranite plutons and the dikes were emplaced at relatively high tectonic levels, probably after uplift and some degree of postmetamorphic cooling.

Potassic granite intrusions, such as the perthite-rich, biotite leucogranite and the fine grained, two-feldspar leucogranite, are commonly associated with late stages of cratonic development (e.g. Glikson and Sheraton, 1972; Anhausser, 1973; Collerson and Fryer, 1978). Several equivalents of Unit 10 and a partial equivalent of Unit 9 occur in surrounding map areas (Figure 7).

6.2 Fine grained leucogranite (Unit 9)

The leucogranite is largely exposed in a poorly defined intrusion zone in the synmetamorphic granitoid rocks (5), which consists of variable proportions of synkinematic granitoid rocks (5a) with their inclusions and leucogranite (9). It also forms small pods which commonly cross-cut the regional tectonic grain of its hosts, like those in the La Poile River area (Unit 15b of Chorlton, 1980b).

Unit 9 consists of fine grained, pink, equigranular two-feldspar leucogranite (9a) of remarkably uniform composition. Local patches of medium grained granite (9b), and minor alkali feldspar-quartz pegmatite, occur in the main intrusion zone around Northwest Brook.

The rocks are largely unfoliated, but are penetratively schistose in small lenses near the Cape Ray Fault, where porphyroclasts of both feldspars form augen in the biotite/muscovite/quartz foliation. They are also foliated in the numerous, small scale faults and shear fractures which were observed in continuous exposures on Northwest Brook.

The fine grained leucogranite (9a) is composed of quartz, plagioclase, alkali feldspar, myrmekite, biotite, and muscovite with small amounts of accessory zircon, epidote, apatite, opaque oxide, and local fibrolite (Plate 47). Quartz (20 to 25 modal per cent) forms both highly strained interstitial domains, and small inclusions in both feldspars.

Plagioclase (25 to 55 modal per cent, approximately inversely proportional to microcline) occurs as lightly sericitized, subrounded oligoclase laths with rims of slightly different optical orientation and degree of sericitization. Alkali feldspar occurs largely as ragged-edged, Carlsbad twinned laths of rod or hair perthite which grades into local internal patches and rims of nonperthitic, gridiron-twinned microcline (Plate 47). Interstitial microcline is also common locally, and myrmekite forms lobes which overprint microcline grain margins.

Biotite (2 to 5 modal per cent) is dark olive brown to olive green, and is locally partly chloritized. In unfoliated rocks, it forms randomly oriented, anhedral flakes with included zircon and local muscovite and/or fibrolite fringes. Muscovite forms small, ragged flakes accompanying biotite and larger poikiloblasts. Fibrolite is locally developed inside muscovite flakes as vermicular domains, and around them as fringes.

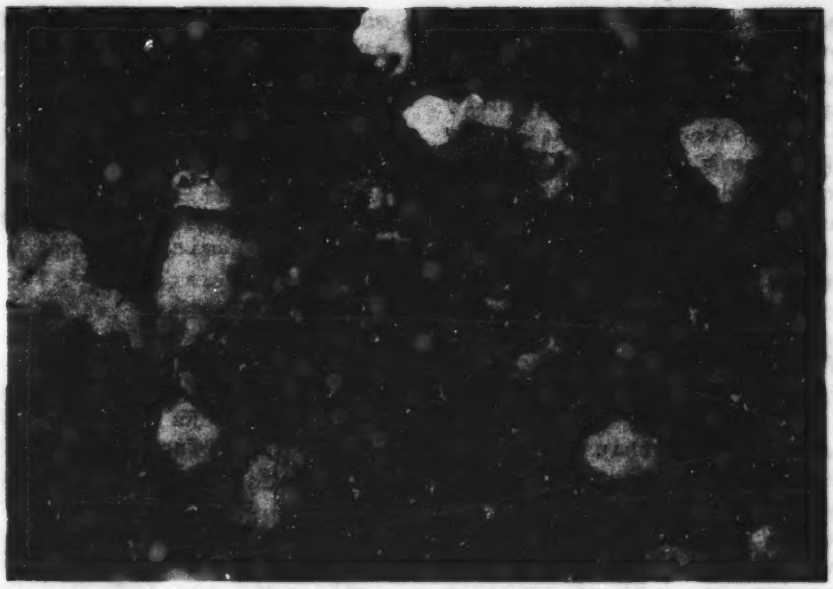


Plate 47: *Photomicrograph of fine grained, allotriomorphic, granular, two-feldspar leucogranite. 80-LC-320. Cross polarized light.*

In the medium grained leucogranite (9b), muscovite is more abundant and biotite less abundant than in the fine grained phase. Contacts between fine and coarse grained phases are microscopically gradational.

The tuffisite (9c) contains angular, highly deformed fragments of tonalite/-trondhjemite, pseudogranophyre, quartz, plagioclase, chlorite, and possibly muscovite, in a dusty, comminuted, quartzofeldspathic matrix. The pseudogranophyre consists of highly altered plagioclase overprinted by cuneiform quartz. The granophyre fragments are probably derived from both the leucogranite and its granitoid host. Altered granitoid rocks near the tuffisite are characterized by bleb-like overgrowths of quartz on mottled-looking plagioclase (An_{60}), and contain abundant apatite.

Brecciated patches and highly fractured outcrops are accompanied by patchy yellow, red, and rarely black alteration along the banks of Northwest Brook. Reddish, hematitic alteration also affects the host rocks, both in the main intrusion zone and locally around the smaller pods removed from the main intrusion zone. Carbonate-filled fractures and cavities are common around brecciated and fractured zones. The carbonate is platy in habit.

Scintillometer readings of 2X to 3X background (total counts) are common in this leucogranite, but do not correlate consistently with degree of alteration.

Relative age and origin:

There are no direct indications of the age of the fine grained, two-feldspar leucogranite (9) and the mafic dike (11d) relative to the fossil-dated Windsor Point Group or to the Cape Ray Fault. The fine grained, pink leucogranite cuts the synmetamorphic granitoid rocks (5), and rarely the modified 'Bay du Nord Group' (3), and truncates the intense, penetrative regional deformation (D_2) affecting both. The deformation associated with this fabric is thought to be late Silurian to early Devonian, culminating with the Cape Ray Fault. The leucogranite is therefore interpreted to be

Siluro-Devonian or younger, and therefore, conceivably equivalent in age to the Windsor Point Group. The two-feldspar leucogranite was apparently affected by late tectonic activity associated with the Cape Ray Fault to the north, and local shearing or minor faulting within the terrane southeast of the fault. It is cut (probably) by a north trending mafic dike (11d) exposed in Northwest Brook.

Several features may be relevant to the origin of the leucogranite:

1. its occurrence within the Rose Blanche phase, and its other hosts, as lenses oriented across the regional tectonic grain, and as an elongated central intrusion zone in the core of the most extensive exposure of synkinematic granitoid rocks (Figure 7);

2. its homogeneous, almost haplogranitic composition, suggesting a minimum melting compositon under uniform melting conditions of T, $P(H_2O)$, and P(total);

3. its generally uniform, fine grained texture, except for subordinate medium grained patches around Northwest Brook, and its lack of phenocrysts, suggesting rapid crystallization under nearly the same conditions as those under which partial melting took place;

4. its two-feldspar (subsolvus) character, suggesting crystallization from a magma at temperatures well below the feldspar solvus. This could occur by quenching a water-saturated magma [$P(H_2O)$ = P(total)] by sudden release of water (which has depressed the solidus temperature and held the magma below the solvus) and thus markedly increasing the solidus, or alternatively by decreasing the $P(H_2O)$ by addition of a volatile species (e.g. CO_2), thus raising the solidus well above the ambient temperature;

5. the occurrence of a tuffisite dike in the core of the main intrusion zone;

6. the abundance of carbonate, and other alteration within and around the leucogranite suggesting that CO_2 was active during and after its crystallization;

7. muscovite in the highly deformed and metamorphosed synkinematic granitoid rocks of Units 5 and 9 universally exhibiting incipient fibrolite development.

Generation of the leucogranite magma by partial melting of the synmetamorphic granitoid rocks during deformation under amphibolite facies conditions (D_2 and possibly D_3), and collection of the magma in tension zones seems likely. The partial alteration of muscovite to form fibrolite occurs extensively in the host rocks, and has probably proceeded to a greater degree at depth. This might have provided the water for conditions of $P(H_2O)$ = P(total) which would facilitate limited partial melting at amphibolite facies and higher temperatures. (Fibrolitization of muscovite accompanying localized partial melting has been discussed also by Eugster (1970)). Since the main effect of the presence of CO_2 in the vapour phase would be to counteract the depression of the solidus produced by H_2O, it is assumed that the partial pressure of CO_2 was very low during the generation of the granitoid magma.

However, a sudden influx of CO_2 into zones of tension or weakness would provide a quenching mechanism for the leucogranite at conditions of T and P(total) under which it was generated, since the effects of both H_2O release and CO_2 addition would raise the temperature of the solidus (cf. Wyllie and Tuttle, 1959; Holloway, 1976; Eggler and Kadik, 1979). The fluxing of CO_2 and H_2O exsolved from the rapidly solidified magma through the Rose Blanche phase and the leucogranite itself, particularly in fracture zones, was responsible for the characteristic carbonate alteration.

CO_2-rich fluids and abundant calcite are not uniquely linked with the leucogranite (9). Carbonate-hosted

amphibolite breccia occurs within the modified 'Bay du Nord Group' near Port aux Basques. In addition, CO_2 is considered to have been an important volatile phase during structurally-controlled, subsolidus metasomatic alteration of the Port aux Basques phase (5b) to the southwest (Dingwell, 1980; Dingwell and Strong, 1981). Late tectonic calcite patches, especially along late fractures, are widespread in the Grandys Lake area.

6.3 Pink, perthite-rich leucogranite (Unit 10)

The pink, perthite-rich leucogranites form three plutons, one extending beyond the map area. These leucogranites are characterized by the presence of abundant, coarse perthite accompanied in most, but not all, cases by oligoclase, low ferromagnesian content (biotite), overall lack of penetrative tectonic fabrics, and discordant contacts with the surrounding country rocks which are locally enclosed as rafts. They are remarkably uniform in composition, and vary generally from medium grained, equigranular granite (10a) to weakly porphyritic, coarse grained, subequigranular granite (10b). Fine grained, porphyritic patches appear locally near the margins.

The bodies are accompanied by very fine grained quartz sanidine porphyry dikes (10c), which may extend far from the mother pluton. They are numerous north of the Cape Ray Fault, and also occur south of the fault. The latter may be related to the Isles aux Morts Brook Granite (Brown, 1976a). Rare, coarsely porphyritic, felsic dikes cut the granites internally.

The perthite leucogranites are generally composed of microcline perthite, plagioclase, and quartz with minor biotite or chloritized biotite, and muscovite. Epidote, sphene, allanite, zircon, apatite, and iron oxide are common accessory minerals. Secondary myrmekite and checkered albite occur locally, as well as carbonate. Proportions of plagioclase to pink weathering alkali feldspar microperthite vary from almost nil (especially in 10a) to just under one. Microcline perthite contains ribbons of 15 to 20 per cent exsolved albite evenly distributed throughout the grains, and is uniformly gridiron-twinned (Plate 48). Small, lightly altered plagioclase laths commonly form inclusions in the microcline. Fringes of plagioclase occur locally along boundaries between microcline perthite grains. Marginal myrmekite occurs locally along alkali feldspar - plagioclase contacts. Plagioclase (oligoclase to andesine) forms subhedral, zoned laths with ovoid, lightly altered cores surrounded in some rocks by a thin oscillitory band inside a thicker sodic rim. Microcline mantles on plagioclase crystals were noted locally. Quartz (approximately 35 modal per cent) forms large polygonized and annealed domains with irregular boundaries towards the feldspars. Fine grains of quartz are distributed along feldspar grain boundaries in some of the granites. Biotite, as anhedral flakes, constitutes less than 5 per cent of the rock, and may be virtually absent. It is commonly dark green in color, but partly chloritized flakes are khaki brown. Muscovite is much finer grained than the biotite, and generally appears to be a later or secondary mineral. It either fringes the biotite or forms clusters nearby. Tiny, irregular flakes commonly overprint feldspar grains. Spectacular, rhombic crystals of sphene and long, thin prisms of zircon occur around the biotite. Epidote also tends to concentrate with the mafic minerals. Iron oxide is very sparse, and is mainly magnetite or hematite.

The quartz-sanidine porphyry dikes (10c) are composed of moderately fine to very fine grained, sparse phenocrysts of quartz, sanidine, and plagioclase set in a spherulitic quartzofeldspathic matrix (Plate 49). Rare muscovite is generally the only other phase present, although abundant muscovite overprints all

Plate 48: *Photomicrograph showing the microcline ribbon perthite characteristic of the perthite-rich leucogranites (Unit 10). 80-LOC-2. Cross polarized light.*

Plate 49: *Photomicrograph of a quartz sanidine porphyry dike (10c), showing phenocrysts of quartz (q) and sanidine (san) in a microgranophyric matrix. DD-80-216. Cross polarized light.*

minerals in dikes cutting the north-central high strain zone. Small cubes of pyrite were noticed in a dike cutting pyrite-bearing felsic blastomylonite south of the Cape Ray Fault.

The southwestern plugs were affected by late metasomatic activity associated with hydrothermal events around the Cape Ray Fault zone, as well as high level deformation. Fractures in the granite are locally lined with checkered albite.

The leucogranite plutons appear to have had little contact metamorphic effect on their previously metamorphosed hosts. Shear zone or fault activity may have masked such effects locally. However, the chlorite and muscovite of highly retrogressed gneissic tonalite and included mafic rocks (4, 1e) (along the western margin of the north-central high strain zone) have been replaced locally by abundant almandine garnet and coarse, prismatic sillimanite.

Relative age and origin:

There is no evidence that the pink, perthite-rich leucogranite plugs are all exactly the same age. The two southern plutons cut the foliated, equigranular tonalite (4a) and its inclusions (1c) after the formation of the penetrative foliation of the tonalite and the phyllonite zone, and before the late activity on the Cape Ray Fault. The more easterly of the two bodies cuts the Windsor Point Group; Thin, aplitic apophyses, possibly related to the leucogranite, intrude the fault zone and are brecciated with the Windsor Point Group volcanic rocks. The westernmost pluton is cut by mafic dikes (11a).

The northwestern plug postdates the penetrative deformation of the tonalite and its inclusions (1) along the southern and southeastern boundary, and also postdates late shearing and retrogression at its eastern contact. It projects as deformed sheets (roots) northwestward into the Stag Hill shear zone, and is also pervasively deformed in the northeast half by the latest activity on the shear zone, probably related to Carboniferous uplift.

The perthite-rich leucogranites occur as discordant plutons emplaced at relatively high levels in the crust at a late stage in the tectonic development of the area. They are mafic-poor, and range from granite to alkali granite. Chemically, they are relatively silicic, have high K_2O/MgO ratios, and display the physical and chemical characteristics of the late orogenic 'alkali' granites described by Rodgers and Greenberg (1981).

Quartz-sanidine porphyry dikes (10c) were probably emplaced into a relatively cool and high level environment, as they are chilled and display uniformly developed spherulitic textures. A few dikes hosted by garnetiferous tonalite (4b, 2c) terrane have been affected by muscovite-producing alteration; therefore, they were intruded while fluids were still present in the latter terrane. If the dikes south of the Cape Ray Fault were emplaced in a cool, high level environment, then they must have been emplaced after the third deformation, uplift, and postmetamorphic cooling south of the fault.

6.4 Mafic and felsic dikes (11a,b,c,d)

Mafic (11a) and felsic (11b) dikes northwest of the Cape Ray Fault are steeply dipping, and trend northeast or northwest. A fresh mafic dike with a well developed diabasic texture (11c) occurs north of Grandys Lake. A north trending mafic dike (11d) at least 10 km long is exposed on Northwest Brook

The mafic dikes (11a) are composed of very fine grained plagioclase, clinopyroxene, local brown hornblende, other ferromagnesian alteration products, and minor carbonate with accessory leucoxene, disseminated magnetite and rare pyrite. Plagioclase forms a felted microlitic matrix. Small tabular plagioclase phenocrysts display

oscillatory zoning, and in some rocks are highly sericitized. There are very rare, anhedral, green ferromagnesian clots. The predominant ferromagnesian mineral is stubby, subophitic, pale brown augite with high dispersion, generally partly altered to pale actinolite or chlorite. Brown hornblende occurs either as acicular prisms or as rims on clinopyroxene, and is commonly altered to deeply pleochroic, fibrous blue-green amphibole. Spherical vesicles are filled with carbonate and locally contain chlorite. Chlorite, actinolite, blue-green amphibole, epidote, and minor biotite are the most common secondary minerals. Margins of the mafic dikes which cut the perthite-rich leucogranite plug (10) in the southwest are foliated and highly enriched in leucoxene, epidote, biotite, and sericite or muscovite.

The felsic dikes (11b) are of two main types: dacitic dikes containing plagioclase and biotite phenocrysts, and more leucocratic dikes containing quartz and plagioclase phenocrysts. An anomalous dacitic dike cutting foliated granitoid rock and paragneiss (4c,2a) is fine grained but lacks phenocrysts.

The porphyritic dacite dikes are composed of phenocrysts of plagioclase and biotite in a microgranitic matrix of quartz, feldspar, muscovite, and biotite with accessory epidote, sphene, fine opaque grains, and zircon. Rare quartz phenocrysts with volcanic embayments were observed. Secondary carbonate patches are common. Plagioclase phenocrysts (approximately calcic oligoclase) display pronounced oscillatory zoning, and commonly form glomeroporphyritic aggregates. Some of the phenocrysts have cloudy cores and sharply bounded, clear rims. Biotite phenocrysts are brown, and contain inclusions of zircon, epidote, and an opaque phase. In some rocks, the biotite is partly to completely chloritized. Epidote is particularly abundant in highly altered rocks, and may locally form coarse crystals. The nonporphyritic dacite dike has an interlocking network of about 70 per cent lath-shaped to acicular andesine in a matrix of very fine grained quartz, up to 5 per cent anhedral magnetite, and about 5 per cent each of olive brown biotite and chlorite flakes overprinting the feldspathic assemblage. Some of these dikes have a primary foliation defined by the alignment of biotite. Most are undeformed, although several of the dikes which occur in the layered metagabbro block near the Long Range Fault are sites of minor ductile shear zones, and have a mylonitic foliation.

The quartz-feldspar porphyries, which are located in the east part of the north-central high strain zone and around Unit 7, are petrographically more variable due to varying degrees of metasomatic alteration. They generally contain quartz and feldspar phenocrysts, and local muscovite porphyroblasts set in a very fine grained, porcellaneous matrix of quartz, feldspar, and muscovite or sericite, locally with rare accessory magnetite, biotite and sphene. Plagioclase phenocrysts are generally unzoned, and are variably altered. Many are partly to completely converted to checkered albite, and others are lightly sericitized or overprinted with carbonate patches.

The diabase dike (11c) contains an interlocking network of acicular plagioclase crystals subophitically enclosed by pale brown clinopyroxene, which is partly altered to chlorite and pale green feathery amphibole. Opaque minerals are extremely abundant. Plagioclase is lightly saussuritized, and patches of secondary carbonate are common. Macroscopic, pale green, ovoid patches are composed of a very fine, pale green, fibrous intergrowth, probably amphibole.

The mafic dike (11d) exposed on Northwest Brook is coarse grained compared to the mafic dikes (11a) north of the Cape Ray Fault. It is composed of blue-green hornblende, biotite,

plagioclase (15 per cent), orthoclase (10 per cent), and quartz (up to 5 per cent) with accessory zircon, epidote, and exceptionally abundant apatite and sphene. Leucocratic minerals are interstitial to ferromagnesian phases. The blue-green hornblende, associated with dusky patches of relict deep brown hornblende, forms stubby crystals and polycrystalline clots which are elongated parallel to the weak foliation. Olive green biotite is approximately equal in abundance to hornblende and contains zircon inclusions. It defines the weak conjugate foliation parallel to the margin of the dike. Plagioclase is highly sericitized, and forms clusters with orthoclase and strained quartz. Orthoclase is nonperthitic to weakly perthitic.

Relative age:

The felsic dikes (11b) are commonly associated with the mafic dikes (11a), and both cut the foliated granitoid terrane (4) post-tectonically. Both also intrude the quartz diorite - megacrystic granite (7). Felsic dikes (11b) were observed cutting layered metagabbro (1b). The mafic dikes (11a) cut the perthite-rich granite (10) in the southwest, and are thus inferred to be younger than the Early to Middle Devonian Windsor Point Group. Pending further investigation, both sets of dikes are therefore assumed to be Devonian or younger.

The diabase dike (11c) is relatively fresh, completely undeformed, and cuts the deformed tonalite and metagabbro terrane (4a, 1c). However, there is no evidence for its age relative to the Windsor Point Group (8), leucogranite plutons (10), or the other dikes (11a,b).

The mafic dike (11d) south of the Cape Ray Fault cuts the foliated Rose Blanche Granite (5) post-tectonically. Its relationship to the fine grained leucogranite (9) is uncertain.

7. STRUCTURAL AND METAMORPHIC DEVELOPMENT

7.1 Overview

Two major regional, northeast trending faults, the Long Range Fault and the Cape Ray Fault, separate the Grandys Lake area into three structural and lithostratigraphic blocks: the Carboniferous sedimentary block (Knight, Part II of this report), the northwestern block, and the southeastern block. The northwestern block exposes ophiolitic crust intruded during deformation and metamorphism by synkinematic tonalite, and is further subdivided into the Little Codroy Pond belt and the Dinosaur Pond belt (Figure 2), which are in contact across another northeast trending fault. The two belts are characterized by a relatively massive zone occupied by ophiolitic gabbro which passes gradationally into amphibolite facies, high strain zones. The southeast block, here referred to as the Bay du Nord zone (Figure 2), is occupied by the polydeformed, amphibolite facies 'Bay du Nord Group' (see Appendix I), intruded by syn-metamorphic granitoid rocks. The Cape Ray Fault, a wide band of mylonite and phyllonite (Brown, 1972, 1973), is overlain unconformably by the Early to Middle Devonian Windsor Point Group. The group is itself highly deformed by the late movement of the fault.

Hydrothermal alteration along the major ductile shear zones, mylonite zones, and faults affected both Devonian and pre-Devonian rocks. The effects of hydrothermal activity are most conspicuous in the north-central high strain zone (Figure 2), around the quartz diorite - megacrystic granite intrusion (7), and around the Cape Ray Fault in the southwest corner of the area. Hydrothermal fluids in this terrane may have been derived mainly from sea or surface water during the early stages of tectonic development, and mainly from metamorphic dehydration reactions during the late stages.

7.2 Timing

A knowledge of the relative timing of structural, metamorphic, and intrusive events among different geological terranes in the area is the key to an accurate synopsis of the geological development of the area. Table 4 is a tentative synopsis of geological events based on information presently available, which includes approximate ages from only a few units within this and adjacent areas:

(1) The early stages of deformation and metamorphism in the southeast part of the area (synchronous with the emplacement of the Rose Blanche Granite) clearly affected the radiometrically dated Ordovician volcanic island arc rocks which interfinger with the metasedimentary rocks of this map area (Chorlton, 1980b). Ages of 446±18 Ma and 449±20 Ma (U/Pb zircon concordia-discordia method) were determined for the dacitic crystal tuffs (Dallmeyer, 1979, 1981; Chorlton, Dallmeyer, and Odom, in preparation) which cap the volcanosedimentary pile. It is considered likely that early thrusting youngs from west to east (Table 2).

(2) The megacrystic La Poile batholith southeast of the map area, which cuts the Rose Blanche synkinematic granitoid rocks (5a), has been tentatively dated as 432±20 Ma (U/Pb zircon concordia-discordia method) (Dallmeyer, 1981; Chorlton, Dallmeyer and Odom, in preparation). A tentative Silurian age of 415±17 Ma (Rb/Sr whole rock) has been quoted for the Rose Blanche phase (Brown, 1976b). However, intense regional deformation of this granite under amphibolite facies metamorphic conditions suggests that this reflects regional metamorphism, probably during D_2 of the host 'Bay du Nord Group.'

(3) A latest Early Devonian or early Middle Devonian age for the Windsor Point Group has been determined from plant fossils (W.R. Forbes, personal communication, 1980, 1981) and spores (D.C. McGregor, personal communication, 1981).

(4) The Carboniferous rocks of the Codroy Valley, mainly the Viséan Codroy Group, were thrown back along the Long Range Fault, with movement involving uplift of pre-Carboniferous rocks next to the fault.

7.3 Structural and metamorphic development of subdomains

The structural and metamorphic history contrast in nature and degree in different parts of the area. Therefore, three fault-bounded subdomains, the Little Codroy Pond belt, the Dinosaur Pond belt, and the 'Bay du Nord' zone (Figure 2) are summarized individually.

7.3.1 *Little Codroy Pond belt*

The Little Codroy Pond belt (Figure 2) comprises the Long Range high strain zone, the layered metagabbro block, and the Stag Hill high strain zone. The two high strain zones merge northeast of the layered metagabbro block, and both grade into the block. A perthite-rich leucogranite pluton (10), the deformed roots of which are exposed in the Stag Hill high strain zone, cuts across the southeast fault boundary of the belt.

The Little Codroy Pond belt comprises rocks from Units 1, 2, and 4. The layered metagabbro block is occupied by cumulate layered metagabbro (1b) interlayered with clinopyroxene metagabbro (1c) near its gradational boundaries. Units 1b, c, and d are transformed into undivided amphibolite of 1e, and together with semipelitic paragneiss and silicified blastomylonite (2a), marble (2b), ultramafic lenses (1a), and synkinematic granitoid rocks (4c, d), occur within the Stag Hill and Long Range high strain zones. The tectonic development of the belt, summarized below, is largely deduced from structural, textural, and metamorphic features of these rocks which are described in the preceding text under the appropriate rock unit.

The layered metagabbro displays a strong, granulite facies L-S to S-L foliation (Plate 50) parallel or nearly parallel to the igneous layering. The foliation was developed either before or at the onset of regional deformation. The early foliation is reflected by the lenticular nature of polygonized olivine, clinopyroxene, and orthopyroxene aggregates, and the granoblastic texture of plagioclase rich domains (Plates 2-4). The high grade assemblages are locally overprinted by amphibolite facies minerals toward the Stag Hill and Long Range high strain zones (Plate 6); this overprint occurred initially at higher temperatures within the area gradational into the layered metagabbro block, i.e. replacement of igneous or granulite facies ferromagnesian minerals by polycrystalline lenses of brown-green hornblende rather than polycrystalline or polygonized blue-green hornblende, followed by late blue-green mottling of the brown-green hornblende.

In the Long Range and Stag Hill high strain zones, composite S-L to L-S fabrics were developed under middle to upper amphibolite facies conditions, producing a composite gneissosity and local rodding in the paragneisses and orthogneisses, and a strong L-S to S-L fabric in the amphibolites. No evidence of deformation prior to metamorphism was observed. The gradual transition of the layered metagabbro subdomain into these zones suggests that the earliest, amphibolite facies 'retrogressive' overprint within the layered metagabbro block is related to the early development of the zones.

The Stag Hill and Long Range high strain zones contain several silicified blastomylonite horizons, and it is

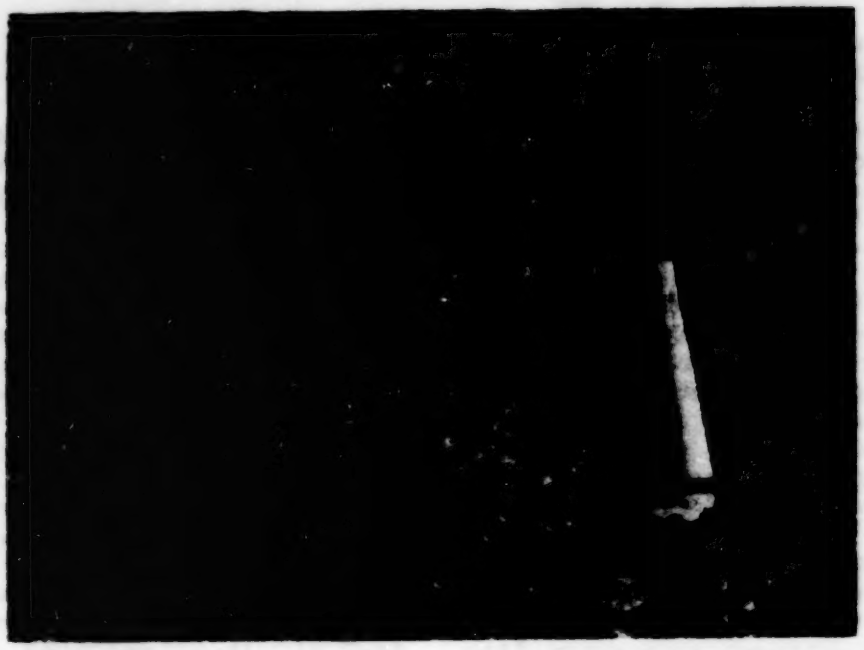


Plate 50: *Granulite facies L-S fabric in layered metagabbro block (1b).*

thought that local juxtapositions of layered metagabbro, ultramafic rocks and metasedimentary rocks near the blasto-mylonites represent tectonic thinning during the early tectonic episode. Early fabrics and structures were gently to moderately inclined, and are thought to reflect low angle thrusting.

The early, amphibolite facies fabrics of the high strain zones were subsequently tightly folded, truncated, and transposed by later deformation which superimposed northeast trends and steepened inclination. The resultant outcrop pattern locally illustrates interference between early, gently to moderately reclined folds and later folds with steep axial planes.

This late deformation is associated with partial greenschist facies retrogression which is most intense along the southeast tectonic boundary and along late internal lineaments of the Stag Hill high strain zone. Late shear zones between the base of the Long Range escarpment next to the marble and the Long Range Fault itself are characterized by a locally mylonitic greenschist facies fabric. The layered metagabbro block as a whole underwent sporadic partial retrogression to greenschist facies, and it is suggested here that local percolation of fluids along zones of weakness in the relatively competent 'dry' block governed the distribution of alteration. The retrogressive metamorphic assemblages are similar to those formed during late shearing along the Long Range Fault and the southeast fault boundary of the Stag Hill high strain zone. Consequently, it is likely that the late development of shear zones and lineaments, the steepening and transposition of early amphibolite facies tectonic fabrics, and the associated retrogression probably occurred in response to Carboniferous uplift between these faults (Figure 3b: fault movement 5).

7.3.2 *Dinosaur Pond belt*

The Dinosaur Pond belt (Figure 2) encompasses the massive metagabbro zone and the north-central high strain zone, which are in gradational contact. An increase in metamorphic grade from upper

greenschist facies to middle or upper amphibolite facies accompanied by the development of a pronounced composite fabric, and a change in structural orientations signify the transition from the massive metagabbro to the north-central high strain zone.

The Dinosaur Pond belt is characterized by high level, ophiolitic metagabbro (1c) and overlying metavolcanic (1d) and metasedimentary (2c, b) rocks engulfed as rafts and xenoliths in biotite tonalite (4a), i.e., a mega-agmatite terrane. Both tonalite and inclusions have been deformed and metamorphosed together, and in most cases the tonalite is more deformed than its hosts. In the massive metagabbro zone, hosts to the biotite tonalite are massive metagabbro and metadiabase with oceanic plagiogranite pods. The north-central high strain zone is occupied by foliated, commonly garnetiferous tonalite (4b) enclosing metasedimentary (2c, b) and mafic meta-igneous (1c,d,e) inclusions.

The massive metagabbro zone was deformed weakly, and metamorphosed to upper greenschist or lower amphibolite grade before uplift, shearing, and local middle greenschist facies retrogression due to movement on the Cape Ray Fault. At the southwest end of the zone the tonalite displays a single, poorly developed, northwest trending cleavage or schistosity away from the Cape Ray Fault. A stronger, northeast trending schistosity is developed toward the fault, a fabric probably related to the fault itself.

The maximum grade increases toward the central and northeastern part of the zone, with the development of the second foliation and more intense overall tectonic fabric. West and northwest of Grandys Lake, the early foliation is transposed or crenulated by the second schistosity, and discontinuous, wavy, muscovite-biotite schist zones characterize several outcrop areas. Strongly foliated to locally gneissic tonalite is exposed near the northeast corner of the map area. The tonalite contains red-brown biotite, typical of higher grade tonalitic rocks in the north-central high strain zone, interlayered with muscovite.

In the north-central high strain zone, the granitoid rocks and their inclusions have undergone deformation involving the formation of a composite, largely northwest striking, moderately dipping schistosity to gneissosity, and northwest and southeast trending, gently plunging lineations and minor folds. This deformation is the predominant structural feature of the area, and took place under middle to upper amphibolite facies conditions. Near the south and southeastern margins of the zone, fabrics trend into the northeast orientations characteristic of the adjacent, massive metagabbro zone.

In the southeastern part of the north-central high strain zone, the early, amphibolite facies regional metamorphic recrystallization is accompanied by substantial metasomatism and probable assimilation ('metasomatic zone' on Figure 2). The main effects are the pervasive muscovitization or fibrolitization of plagioclase, the overprinting of most minerals by quartz, the 'leaching' of biotite to a pale pseudomorph accompanied by exsolution of fine grained rutile, and the local production of abundant, red, poikilitic to skeletal garnets (Plate 22). Oxidation and leaching of sulfides in a few rusty, schistose exposures, and locally profuse, fine grained magnetite are also characteristic of this zone. This very complex zone requires much more detailed documentation than attempted here.

Greenschist facies retrogression in the Dinosaur Pond belt, linked with uplift along the north side of the Cape Ray Fault (Figure 3b: fault movement 3), is displayed in both zones of the belt, but is most obvious in the amphibolite facies, north-central high strain zone.

Inconsistent, patchy retrogression to greenschist facies minerals affects most of the zone, but rocks adjacent to the western margin and around some of the prominant lineaments are more completely retrogressed. The most common forms of retrogression in most of the rocks are the sericitization of feldspar and the formation of fibrous blue amphibole around earlier metamorphic hornblende and other ferromagnesian minerals. Partial chloritization around the margins of garnets, the occurrence of epidote/allanite aggregates, and patchy carbonate are more localized. Retrogression is most evident around the late microfractures. The thoroughly retrogressed rocks at the western margin were locally contact metamorphosed later by to the northwestern perthite-rich leucogranite pluton (10).

The relatively intense, northeast striking foliation which occurs along the fault in the massive metagabbro zone grades through a wide zone of phyllonite into the fault zone mylonite in the southwest corner of the area. Tuffisite dikes locally cut the mylonite parallel to its layering; fragments of tuffisite are found in the volcaniclastic rocks of the Windsor Point Group. Some of the deformation associated with the Cape Ray Fault system postdates the early mylonitization, since northeast striking, southeast dipping shear and fracture zones also affect the Windsor Point Group and the southwestern leucogranite plugs (10) which intrude the fault phyllonite; these are probably related to late deformation stages of the 'Bay du Nord' zone.

7.3.3. *'Bay du Nord' zone*

The 'Bay du Nord' zone is largely occupied by the 'Bay du Nord Group' (3), cut by veins and sheets of granitoid rocks (5) after the first period of deformation and before the second. The Windsor Point Group (8) occupies the Cape Ray Fault zone, which forms the northwestern boundary of the subdomain.

The first certain link in tectonic history between the zones separated by the Cape Ray Fault System is provided by deformation which affected the Windsor Point Group; however deformation which resulted in the initiation of the fault, prior to the deposition of the group, can tentatively be correlated on both sides of the fault (Tables 2, 4).

The structural history of the 'Bay du Nord' zone is divisible into three major and one minor regional deformation episodes, here denoted as D_1 to D_4.

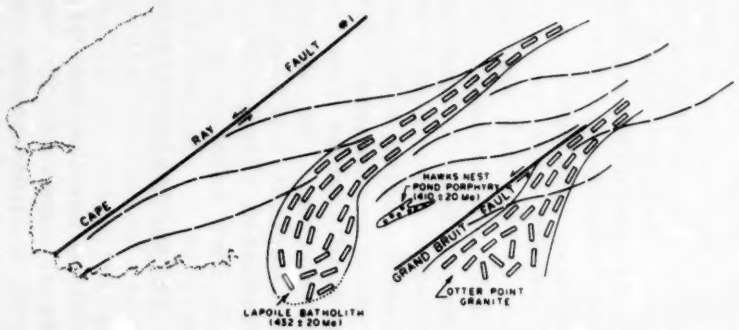
D_1: The first deformation resulted in an early foliation (S_1) subparallel to initial layering, now preserved locally as planar inclusion trails in almandine garnet, planar to slightly curved trails in staurolite of the metasedimentary rocks (Plates 26-30), and a micaceous schistosity. S_1 is more commonly present as a micaceous schistosity in the west part of the zone than in the east.

Amphibolite facies metamorphic grade, the local production of migmatitic veining, and the emplacement of sheets of synkinematic granitoid rock (5) followed D_1 recumbent folding and tectonic burial. Migmatitic banding is along S_1 in metasedimentary rocks, as are gneissic schlieren in the western exposures of granitoid rock (5a).

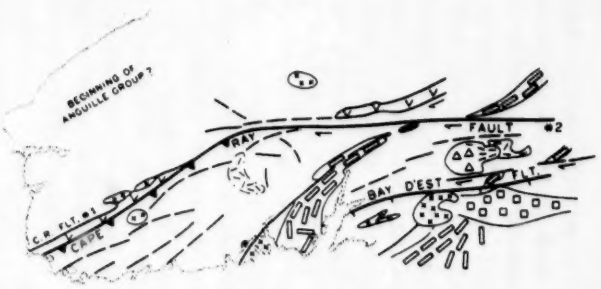
D_2: The second deformation occurred under the ambient amphibolite facies conditions, and resulted in the development of the main, northeast striking, southeast dipping schistosity and locally, tight folding of the earlier fabric. It culminated in the development of the Cape Ray Fault (Figure 3b, fault movement 3), and the deposition of the Windsor Point Group along it (Figure 8a,b).

In fact, late stages of D_2 may be the first stage of deformation affecting the Windsor Point Group.

FIGURE 8: *Early Devonian and later tectonic development of southwest Newfoundland. Present day coast in faint dots for reference.*

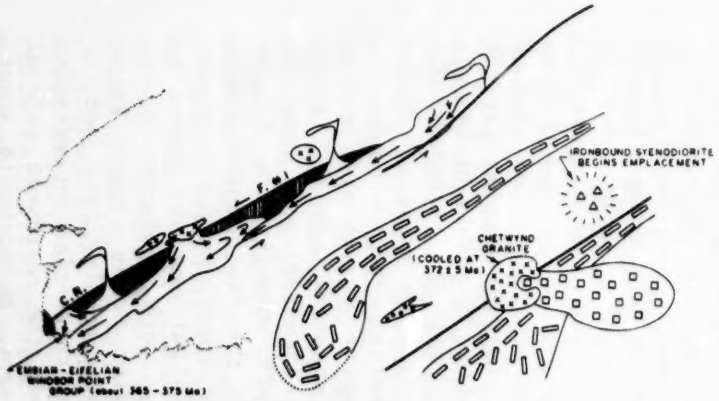


8a. *Initiation of the Cape Ray Fault in the Early Devonian, culminating from the D_2 deformation episode of the 'Bay du Nord' zone. Megacrystic granitoid batholiths, and porphyritic microgranite are deformed during D_2.*



8c. *Uplift of the deepseated, amphibolite facies 'Bay du Nord' terrane against the Windsor Point Group in the southwest via high angle thrust, block and strike-slip faulting between Cape Ray Fault No. 2 and the Bay d'Est Fault.*

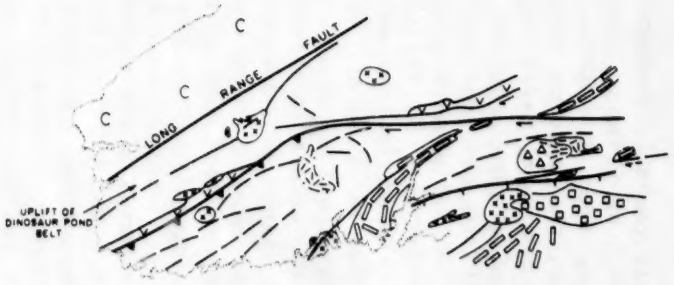
two-feldspar leucogranite



8b. *Deposition of Windsor Point Group fluviatile sediments and a bimodal volcanic suite either accompanied or followed early sinistral wrench movement on the Cape Ray Fault. Note differential uplift (scissors movement) associated with wrenching. Local emplacement of granitoid plutons.*

perthite-rich leucogranite

ironbound syenodiorite-granite



8d. *The uplift of the Little Codroy Pond belt between the Long Range Fault and the southeast boundary of the Steg Hill high strain zone, effecting Carboniferous (Visean) rocks on the northwest side of the Long Range Fault.*

This episode is probably responsible for most of the linear fabric elements away from the Cape Ray Fault zone. In the western part of the zone, S_1 was isoclinally folded or transposed during the second deformation (Plate 28), and porphyroblastic garnet and staurolite form augen in the strong S_2 foliation (Plates 24, 26). An intense schistosity parallel to a local, weak, gneissic segregation (S_2) was developed in the granitoid sheets of the western part of the zone. Pegmatites and small quartz veins were probably emplaced during this period, and massive, northeast trending quartz veins may have developed afterwards along major D_2 slide or shear zones. In the central part of the zone, migmatitic layering in the metasedimentary rocks (3a) and gneissic schlieren in the granitoid rocks (5a) are chaotically folded around moderately to gently plunging, northeast trending hinges.

D_3: The third deformation began under the ambient amphibolite facies conditions, and culminated in the uplift of the buried amphibolite facies 'Bay du Nord Group' terrane against the Windsor Point Group in the Cape Ray Fault zone (Figure 3b, fault movement 4). Crenulation cleavage and minor folds of earlier fabrics in the pre-Devonian terrane are especially noticeable beside the fault zone, and a schistosity was developed in the Windsor Point Group. (Folds and crenulation further east were probably coaxial with D_2 structures.) D_3 fault movement produced mylonite zones in the formerly amphibolite facies rocks along the fault contact with the Windsor Point Group. Northeast striking foliations and zones of fault gouge were produced in the Windsor Point Group. Shear zones were inhomogeneously developed in the late, perthite-rich leucogranite plutons along the northwest side of the fault zone. Moderate to steep, southeast plunging mineral lineations and fold axes occur in the fault contact zone, and affected both amphibolite facies rocks and the Windsor Point Group. Wilton (1981) related gently northeast and southwest plunging fold hinges in the Windsor Point Group, southwest of the map area, to northwesterly directed, arcuate thrusting southwest of the map area. Brown (1975) suggested that several northeast trending 'slides' south of the map area were antithetic to the main, high angle thrust movement which affected the Windsor Point Group along the Cape Ray Fault. The strong, blastomylonitic to mylonitic fabrics in synkinematic granitoid rocks along the east part of the Cape Ray Fault in this map area are related to oblique, strike-slip movement of this splay of the fault (Figures 7, 8c). East striking shear or fracture zones also cut across the fine grained, two-feldspar leucogranite (9) on Northwest Brook.

D_4: The regional effect of the fourth deformation (D_4) in the internal part of the 'Bay du Nord' zone was confined to kink bands and small scale fault or fracture zones; strain-slip cleavage is locally and inhomogeneously developed. The late deformation may have reactivated older fault zones, and most of the chevron folding, kinkbanding, and crenulation cleavage affecting the Windsor Point Group is probably largely related to this period. The deformation is probably Carboniferous, and related in time to the Carboniferous rocks of the Codroy Valley and uplift of the Little Codroy Pond belt (Figure 3b, fault movement 5; Figure 8d).

7.4 Contact metamorphic/metasomatic effects

Two intrusions in the Grandys Lake area show thermal contact efects: (i) the perthite-rich leucogranite pluton (10), where it intersects rocks sheared

and retrogressed to greenschist facies along the fault between the Little Codroy Pond belt and the Dinosaur Pond belt; and (ii) the quartz diorite-megacrystic granite (7), the effects of which might be associated with hydrothermal convection. In addition, the fine grained, two-feldspar leucogranite (9) caused metasomatic alteration affecting itself and its hosts.

The leucogranite pluton (10) which intersected the retrogressed fault contact between the Little Codroy Pond and the Dinosaur Pond belts caused contact effects, including garnet replacement of chloritized patches in retrogressed amphibolite inclusions, and sillimanite replacement of muscovite in the late, strain-slip cleavage and in sericitized plagioclase. Traces of the overprinted minerals remain. Near the southeast contact of the pluton, very large, equant almandine garnets (locally over 2 cm in diameter), with an earlier foliation preserved as magnetite inclusion trails, occur in a coarse grained tonalite mainly composed of plagioclase, quartz, and red-brown biotite. Quartz-sanidine porphyry dikes (10c) projecting into the north-central high strain zone are randomly overprinted by muscovite, suggesting that fluids were still active in this zone at the time of leucogranite emplacement.

The quartz diorite-megacrystic granite body (7) in the northwest corner of the area affected its already foliated, amphibolite facies hosts to an uncertain lateral extent. The contact metamorphism varies from retrogression to local prograde metamorphism; in some cases, the latter has been superimposed on the former. Retrograde effects include widespread chloritization and muscovitization. Prograde effects include the production of garnet from retrograde chlorite patches, and sillimanite or fibrolite bundles from muscovite or muscovitized feldspar (cf. Eugster, 1970; Vernon, 1979). Quartz-feldspar porphyry dikes (11b) intruding the quartz diorite were metasomatized.

The fine grained, two-feldspar leucogranite (9) is associated with alteration in the form of carbonate-filled fractures or cavities and patchy hematitization affecting itself and its host synkinematic granitoid rocks. Both the leucogranite and its hosts were locally brecciated.

7.5 Major faults

The Cape Ray and the Long Range Faults are Devono-Carboniferous systems of several individual faults, which intersect older thrusts, ductile shear zones, and blastomylonite zones. The Cape Ray Fault system can be divided into two fundamentally distinct faults, Cape Ray Fault #1 and Cape Ray Fault #2 (Figure 7). Cape Ray Fault #1 both preceded and overlapped the deposition of the Windsor Point Group, and was succeeded by Cape Ray Fault #2. The Long Range Fault system is represented in the map area by the main Long Range Fault itself, and by the fault which forms the southeast boundary of the Stag Hill high strain zone (Figure 2).

The Cape Ray Fault system probably became active in the Early Devonian (Chorlton et al., in preparation) (Figure 3b, fault movement 3; Figure 8a). The tonalite and ophiolite terrane along the north side of the fault grades into a phyllonite to mylonite zone forming the basement to the late Early or Middle Devonian Windsor Point Group deposited along the fault scarp (Figure 8b). Clastic rocks of the Windsor Point Group contain fragments of fault mylonite, foliated tonalite, and ophiolitic gabbro (Brown, 1975), indicating that the massive metagabbro subdomain must have been at least partly exposed, probably uplifted by the vertical component of the earliest fault movement. The fault is interpreted here as a wrench fault culminating from the second deformation episode which affected the Bay du Nord zone (Chorlton, in preparation), and probably caused a substantial, but presently unknown, sinistral displacement between the northwest and southeast blocks.

However great the magnitude of early strike-slip movement along the initial Cape Ray Fault, the late activity of the fault system resulted in more obvious vertical than lateral displacement. The buried, amphibolite facies terrane southeast of the Cape Ray Fault was subjected to further deformation which culminated in uplift against the greenschist facies Windsor Point Group through reverse faulting and oblique strike-slip movement (Figure 3b, fault movement 4; Figure 8c). Moderate to steep, southeast plunging mineral lineations in the 'Bay du Nord Group' along the southeast fault contact with the Windsor Point Group may signify a transport direction. Minor ductile shear zones within the uplifted block, as well as trains of en echelon tension gashes provide evidence of dextral shear during this stage, probably responsible for the broad Z-shaped flexure of the main fault zone and the necking out of remnants of the Windsor Point Group in the inflexion. There is no discontinuity of the Windsor Point Group southwest of the inflexion or northeast of it. Therefore, late stage dextral fault displacement was apparently not very large.

Movement on the Long Range Fault postdated the main activity of the Cape Ray Fault system (Figure 8d). The fault plane is vertical to steeply dipping in most places, but is locally moderately inclined to the southeast (Mook, 1926),and forms a high angle thrust. Open folds in Carboniferous sedimentary rocks were truncated and the sedimentary rocks locally backthrust by the uplift of a strip of the ophiolitic terrane (Mook, 1926; Knight, 1982) (Figure 3b: fault movement 5). The exhumed belt is bounded to the northwest by the Long Range Fault and to the southeast by the near vertical southeast margin of the Stag Hill high strain zone, and represents the lower, largely ophiolitic, imbricate unit. Thus, it is suggested that high angle, reverse faulting was an important component of the Long Range Fault, and that the fault is primarily a dextral wrench fault (Phair, 1949; Webb, 1969; Belt, 1969).

8. ECONOMIC GEOLOGY

8.1 Economic potential of the southern Long Range Mountains, including the Grandys Lake area

Re-interpretation of the geology of southwest Newfoundland suggests that terranes on both sides of the Cape Ray Fault have a greater mineral potential than previously envisioned, particularly for copper-bearing massive sulfides, porphyry copper, and gold.

Several settings represented by Ordovician terranes in this area are favorable for massive sulfide deposits. Hypabyssal and extrusive mafic volcanic parts of the ophiolite, i.e., massive metagabbro and metadiabase (1c) to mafic metavolcanic and metasedimentary rocks (1d,e, 2c), could host Cyprus-type massive sulfide (Fe-Cu) deposits (Hutchinson, 1973, 1980; Strong, 1974) along the belt between the Cape Ray and Long Range Faults. Besshi or keislager type massive sulfides (Cu-Zn) are also potentially associated with graywackes and mafic volcanic rocks in arc-trench gaps (Sawkins, 1976; Hutchinson, 1980), the latter perhaps represented either by the metasedimentary rocks and interlayered amphibolites of the modified 'Bay du Nord Group' (3a,b), or by the metasedimentary and associated metavolcanic rocks (2, 1d,e) northwest of the Cape Ray Fault. Alternatively, 'early arc' volcanics (Dean, 1977), potentially hosting the 'volcanogenic primitive type' (Cu-Zn) massive sulfides (Hutchinson, 1980), could also be considered possible analogues for the mafic metavolcanic rocks in either of the above units, since the tectonic affinities of these rocks have not yet been investigated. A geological setting resembling parts of the Grandys Lake area has been described in northern Spain, where massive sulfides (Cyprus-type) are associated with ophiolitic rocks, derivative amphibolite, and chemically altered, gedrite-bearing amphibolites interbedded with calcareous, siliceous, and carbonaceous marine metasedimentary rocks (Badham and Williams, 1981). Any massive sulfide mineralization in the Grandys Lake area would probably have been affected by magmatic recycling during the generation of abundant granitoid rocks, and possibly selectively remobilized or concentrated by hydrothermal/metasomatic activity along the many mylonites and high strain zones which characterize the area.

Porphyry-type mineralization is known elsewhere in the Appalachian system (e.g., Gaspé Copper), associated with rocks similar to quartz diorite, quartz monzonite and granite plutons northwest of the Cape Ray Fault (Hollister et al., 1974). One such pluton (Unit 7) shows evidence for late magmatic hydrothermal alteration accompanied by orthoclase porphyroblast development. Several similar, post-tonalite, pre-Windsor Point Group granitoid plutons, some with disseminated Cu mineralization, have been observed northeast of the Grandys Lake area (Herd and Dunning, 1979; Kean and Jayasinghe, 1981; G.R. Dunning, personal communication, 1981) and southwest of the area (D.C.H. Wilton and C.B. Mackenzie, personal communication, 1979). This suite is possibly intersected at higher tectonic levels elsewhere by the present erosion surface, since the Devonian vertical movements are not expected to have affected the whole terrane uniformly. The age(s) of these plutons is uncertain, but could range from Middle Ordovician to Early Devonian, based on field relationships. Evidence of hydrothermal activity, ranging in age from that associated with the early thrust zones (Ordovician) to that associated with the Cape Ray Fault and other late structures (Devonian), is common in this terrane. Mineralizing granitoid rocks which encountered coeval hydrothermal systems during emplacement, and caused increased or renewed convection, may have produced significant mineral enrichment. The

geometry of the alteration zones may have been dictated by pre-existing structures and fluid conduits, and thus atypical of other porphyry systems.

The geology on both sides of the Cape Ray Fault exhibits several features favorable for gold mineralization, particularly in synmetamorphic vein and shear systems. Ordovician supracrustal sequences on either side of the fault were deposited on largely mafic to intermediate crust, probably locally ultramafic at depth. Mafic metavolcanics occur as part of the Ordovician supracrustal assemblage northwest of the fault, and are protoliths for at least some of the 'Bay du Nord' amphibolites southeast of the fault. Mafic and ultramafic magmatic rocks are generally enriched in trace gold relative to other magmatic rocks (Boyle, 1979), and mafic volcanic rocks, with or without intercalated synvolcanic sedimentary rocks, are very commonly associated with gold-producing mines in the Canadian Shield and Cordilleran areas (Hodgson et al., 1982). Secondary concentrations of gold in metamorphic quartz and quartz-carbonate veins are common in many gold camps.

An even more important aspect of the area with respect to gold potential is that most of the pre-Devonian rocks have been polydeformed and metamorphosed under amphibolite facies conditions, processes accompanied by hydrothermal/-metasomatic activity along numerous ductile shear zones. If Au were derived from mafic volcanic or ophiolitic rocks, low water to rock ratios in between shear zones would favor the selective enrichment of the metamorphic rocks in Au and other rare elements relative to the more abundant base metals (Kerrich and Fryer, 1981; Kerrich 1981); therefore, Au-enriched fluids would probably have migrated preferentially to shear zones or hydrothermal conduits during metamorphism, and precipitated where the chemical environment was favorable. Kerrich (1981) suggested that the prograde greenschist facies to amphibolite facies transition is a particularly favorable stage for gold mobilization, since fluids bound in silicates in almost all rocks are released to provide significant fluid migration, directed down temperature, with a suitably low water/rock ratio. Thus, greenschist facies rocks located just above this transition are relatively likely to host auriferous vein type deposits. Such a transition in the Grandys Lake area coincides with the upper greenschist-lower amphibolite facies massive metagabbro zone, and also coincides with the transition between the north-central high strain zone and the massive metagabbro zone (Figure 2).

Another noteworthy type of gold mineralization in the Canadian Shield are vein occurrences hosted by trondhjemitic to dioritic, locally gneissic batholiths in the Atikokan area of western Ontario (Wilkinson, 1982). The occurrences are sited along prominant lineaments signifying minor faults or shear zones traversing the granitoid terranes, and are accompanied by Ca and CO_2 enrichment (Wilkinson, 1982). The batholiths and their enclaves described by Wilkinson bear a general resemblance to the deformed granitoid rocks (4) and their enclaves northwest of the Cape Ray Fault.

Gold-bearing veins along shear zones in a smaller, synvolcanic, trondhjemitic intrusion in northwestern Ontario were recently studied by Poulsen and Franklin (1981), who came to the following conclusions:

(1) The gold-bearing veins were developed later than porphyry copper mineralization associated with the same pluton.

(2) The ductile shear zones of this complex were developed under the greenschist facies conditions which affected the associated metavolcanic rocks and porphyry mineralization, and were accompanied by the influx of Mg,

K, and H_2O and the removal of Na and Ca through the dissolution of plagioclase and formation of muscovite.

and either

(3) Metasomatic alteration accompanying gold mineralization was accomplished by acidic fluids with a relatively high fO_2/fS_2. The porphyry copper zone may have essentially been destroyed by oxidation of the sulfide minerals, thus enhancing the solubility of copper in the presence of HSO_4 or SO_4 complexes and stabilizing iron as oxides. Copper would thus be transported entirely from the system. Subeconomic gold associated with the porphyry copper may therefore have been selectively redistributed and deposited in shear zone controlled quartz veins.

or

(4) The gold was introduced from an external source, metamorphic fluids or seawater.

Conclusion (3) might be of interest in considering both the possibility of porphyry-type granitoid rocks occurring northwest of the Cape Ray Fault, and the reactions evident in the 'metasomatic' parts of the north-central high strain zone and around the quartz diorite-megacrystic granite (Unit 7). It is noteworthy that this mechanism of remobilizing porphyry copper mineralization through oxidation would also be effective in the remobilization of other sulfide concentrations encountered in ductile shear or high strain zones.

8.2 Lake sediment geochemical survey

Several geochemical anomalies were detected during the lake sediment geochemical survey of southwest Newfoundland (Butler and Davenport, 1980). The most noteworthy are of Cu, Pb, Zn, U and Ag. Cu, Pb, Zn, and U anomalies occur within the map area; the Ag anomalies are confined to the Rose Blanche area (110/9) and La Poile River area (110/16). The distribution of anomalies corresponds to the distribution of rock types and structural features (Figure 9).

Broad Cu anomalies (Figure 10a) between the Cape Ray Fault and Long Range Fault probably reflect well exposed parts of the ophiolitic Long Range Mafic-Ultramafic Complex (1) and overlying metasedimentary rocks (2c). Similar Cu anomalies also extend to the south coast between the communities of Isles aux Morts and Rose Blanche, and along blastomylonite zones southeast of the fault (Figure 10a). These probably reflect exposures of amphibolite, derived from either ophiolitic or 'early arc' mafic volcanic, volcaniclastic, or subvolcanic rocks south of the fault (Figure 9a), and remobilization of Cu along shear zones. Similar Cu patterns occur over 'early arc' and ophiolitic volcanic rocks in the Central volcanic belt (Butler and Davenport, 1978). Amphibolite exposures along the highway locally contain disseminated chalcopyrite mineralization. A highly weathered, rusty, silicified blastomylonite zone (termed a 'slide' by Brown; 1975) exposed along the highway near Burnt Island, and pyritized, silicic, blastomylonite zones on Nitty Gritty Brook in the La Poile River area and in the southwest corner of the Grandys Lake area may represent the type of mineralization to be found along these horizons.

Anomalous Pb (Figure 10b) can be correlated mainly with abundant cataclastic zones or minor faults southeast and north of the Cape Ray Fault, and to a lesser extent along the fault itself. Lead anomalies along the Cape Ray Fault zone project along a splay east of the Grandys Lake area. An anomaly also occurs in the Bay du Nord Group near the contact of a perthite-rich leucogranite near Rose Blanche.

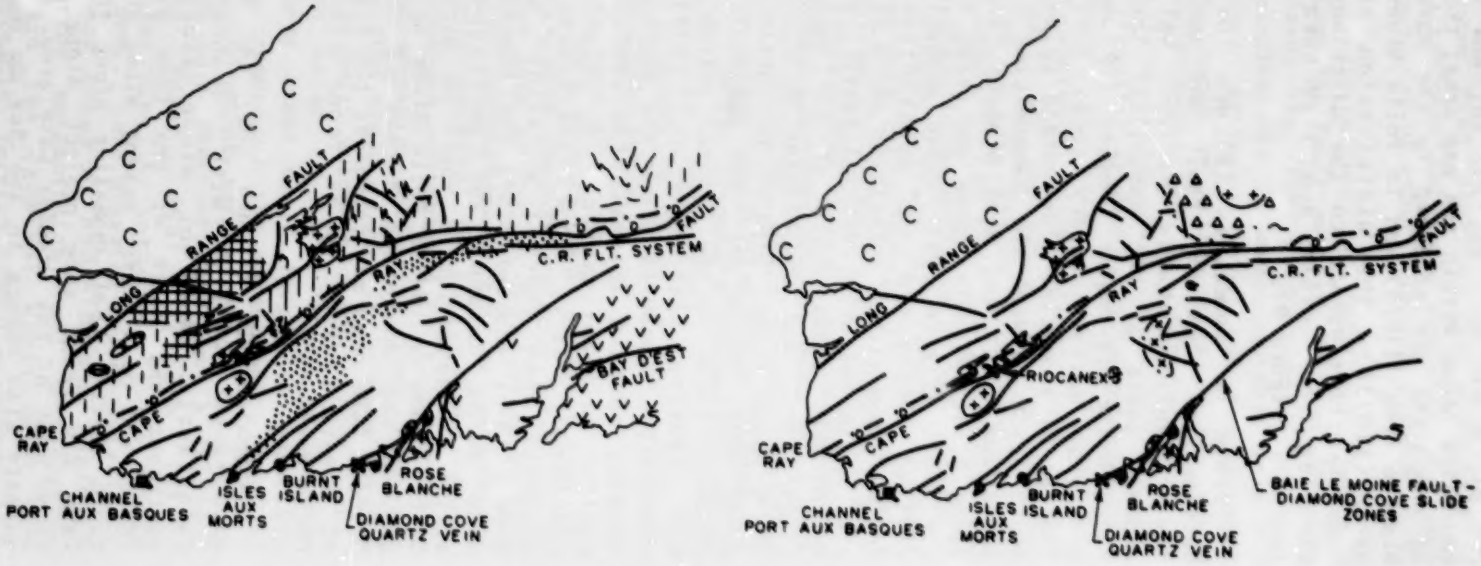


FIGURE 9: *Distribution of (a) ophiolitic rocks, amphibolite, tonalite, and metasedimentary rocks, and (b) late tectonic granitoid rocks, with reference to known prospects and major structures. For lake sediment geochemical distribution of Cu, Pb, Zn, U and Ag see Figure 10.*

EXPLANATION

- *Ordovician, calc-alkaline volcanic and volcaniclastic rocks*
- *Ordovician metasedimentary rocks (shown only northwest of Cape Ray Fault)*
- *Ophiolitic high level gabbro, diabase, basalt*
- *Ophiolitic high level gabbro, diabase, basalt, engulfed by tonalite*
- *Ophiolitic layered, cumulate Ol-bearing metagabbro*
- *Amphibolite of partly ophiolitic, partly "island arc," mafic volcanic and subvolcanic origin*
- *Two-feldspar (subsolvus), two-mica leucogranite*
- *Perthite-rich (hypersolvus to subsolvus) leucogranite*
- *Quartz diorite to megacrystic granite*
- C C *Carboniferous sedimentary rocks*
- D D D *Devonian volcanic and sedimentary rocks*
- *Exhumed reverse block fault with unconformity*
- *Minor fault, ductile shear zone lineament*
- *Major fault*

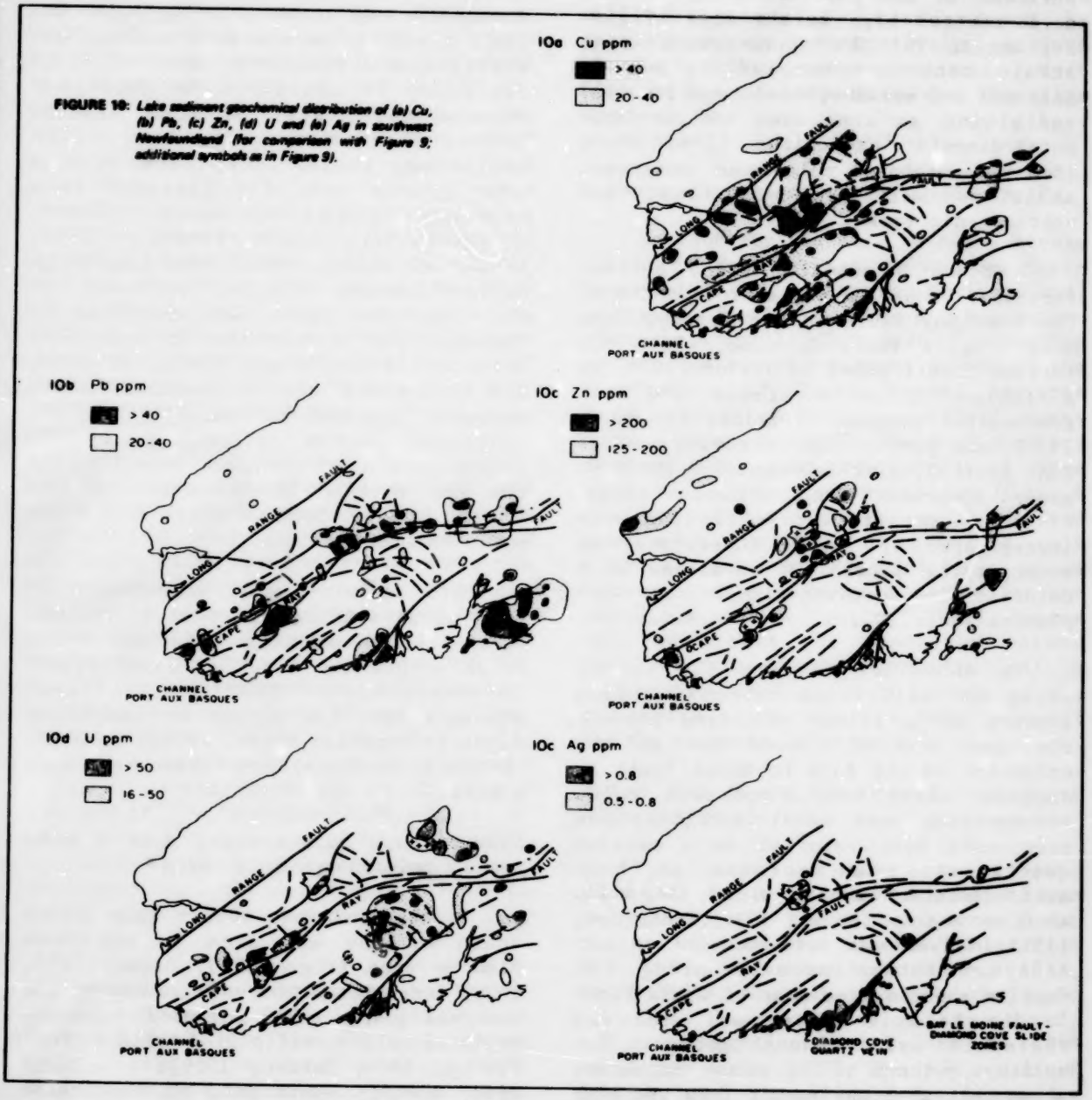


FIGURE 10: *Lake sediment geochemical distribution of (a) Cu, (b) Pb, (c) Zn, (d) U and (e) Ag in southwest Newfoundland (for comparison with Figure 9; additional symbols as in Figure 9).*

Zn distribution (Figure 10c) generally mimics Pb, although anomalies are smaller. However, Zn is notably enriched in the lake sediments of the north-central high strain zone (Figure 2), unlike Pb. The north-central high strain zone is occupied by highly deformed and metamorphosed tonalite (4b) containing an abundance of assorted metasedimentary xenoliths (2c), among them metamorphosed calcareous mudstone, shale, psammite, chert, clay, and volcanogenic rocks.

A broad U anomaly occurs between Northwest Brook and Garia Brook south of the Cape Ray Fault in the Grandys Lake area (Figure 10d). It covers both the terrane investigated by Taylor (1970) as a follow up to a stream sediment geochemical program by Brinex (Sampson, 1972), and part of the intrusion zone of fine grained, pink leucogranite (Unit 9) around Northwest Brook. Numerous lenses of the latter are exposed in the area investigated by Taylor (Chorlton, map accompanying 1980b). U anomalies also coincide with perthite-rich leucogranite plutons (Unit 10).

Ag anomalies (Figure 10e) occur along the silicified tectonic slides (Brown, 1975, 1976a) extending between the coast west of Diamond Cove and the extension of the Baie le Moine fault or ductile shear zone. Sporadic gold, accompanying base metal sulfides, has previously been reported in a massive quartz vein and screens of host metasedimentary schist along the slide at Diamond Cove (Howse, 1934; Snelgrove, 1935). Silver was not included in the assays. Another anomaly along the ductile shear system east of Garia Brook in the La Poile River map area may therefore merit investigation. The bullseye pattern of the silver anomalies along this zone may result from the high detection limit of Ag relative to its natural abundance and the rarity of ponds along the zone.

8.3 Previous exploration

Prospecting in the Grandys Lake area (110/15) and the adjacent, more accessible map areas (110/10,11,14) was limited before the mid-1970's. The first significant prospect was a gold discovery in massive vein quartz at Diamond Cove, west of Rose Blanche (Figure 9) (Howley, 1918; Howse, 1934; Snelgrove, 1935). Later, the Diamond Cove quartz vein was assessed as a source of industrial silica (Tater, 1964; Butler, 1967; Fleming, 1968; Butler and Greene, 1976). The Long Range Mafic-Ultramafic Complex northwest of the Cape Ray Fault was explored by Canadian John's Manville in search of asbestos (Holley-Hime, 1961). In 1968, Brinex carried out a regional stream sediment geochemical survey (Sampson, 1972), a program followed up by the investigation of uranium anomalies in the east part of the Grandys Lake area (Taylor, 1970). None of these endeavours met with much success.

More recently, gold accompanied by base metal sulfides in vein quartz has been discovered near Isle aux Morts Brook within the Cape Ray Fault system (Northern Miner, 1977). Since then, Riocanex Ltd. has proven a significant deposit (Northern Miner, 1978). However, no plans for development have been made public.

Diamond Cove quartz vein (Rose Blanche area), and other quartz veins:

The Diamond Cove quartz vein occurs south of the map area in the Rose Blanche area (Figure 9b). Brown (1975, 1976) interpreted the vein as one of the numerous quartz veins and pods which are emplaced along silicified slides (cf. Fleuty, 1964; Hutton, 1979). A silicified, locally pyritized, blastomylonite and several large quartz veins in the southwestern part of the map area could host mineral occurrences like the Diamond Cove quartz vein.

Gold discoveries in the Diamond Cove quartz vein near Rose Blanche first stimulated public interest in 1899 (Howley, 1918; Snelgrove, 1935), and again in 1934 (Howse, 1934; Snelgrove, 1935). According to Snelgrove, the vein is a massive, east trending pod which has a maximum width of 220 ft (67 m), and is composed of approximately two thirds massive quartz to one third metasedimentary screens (graphitic and sericitic schist). The screens were chemically altered by hydrothermal activity associated with the vein, the sericite or muscovite schist silicified and the graphite schist greatly enriched in graphite. Away from the main vein, smaller quartz veins are hosted in more massive carbonaceous slate and quartzite. A tourmaline-quartz-muscovite vein is also exposed north of the main vein.

The metallic mineralization was described by Snelgrove (1935) as largely consisting of pyrite, commonly accompanied by arsenopyrite and less commonly by sphalerite. The mineralization is erratic, and is hosted by the metasedimentary screens, their contacts with the massive quartz, and by the quartz as disseminations and fracture fillings. No visible gold was observed. Assays (Howse, 1934; Snelgrove, 1935) reveal that Au values are extremely erratic, ranging from nil to 32 oz + 1 dwt + 8 gr per long ton (1099.6 g/t).

Gale (1967) reported minor pyrite, chalcopyrite, sphalerite and galena in small quartz veins west of Isles aux Morts.

According to assessments by Butler (1967), Fleming (1968), and Butler and Greene (1976), the Diamond Cove quartz vein contains too many country rock screens to be commercially viable as an industrial silica deposit.

Long Range Mafic-Ultramafic Complex:

The asbestos potential of the ultramafic rocks in the Long Range Mafic-Ultramafic Complex was assessed (Holley-Hime, 1961) on the basis of studies by Phair (1946, 1949). The results were negative, since the ultrabasic rocks in most places were neither adequately retrogressed to serpentine nor penetratively strained during the retrogression. Most occurrences of serpentine are very fine grained, and lack the long cross fibres desirable.

Uranium anomalies west of Garia Brook:

In 1968, Brinex carried out a stream sediment geochemical survey on their concession in southwest Newfoundland, analysing for Ba, Cu, Pb, Ni, Mn, and Mo (Sampson, 1972). The most interesting result was a uranium anomaly west of the headwaters of Garia Brook, an area underlain by foliated granitoid rocks (5a) with several metasedimentary screens (3a), cut by lenses of fine grained, pink leucogranite (9). A follow-up program in the area involved geochemical analyses of silt and rock samples, and packsack drilling in an attempt to find a bedrock source for the anomalous uranium (Taylor, 1970). Taylor concluded that the anomalous values resulted from uranium concentrations in radioactive inclusions in biotite of the metasedimentary screens, and were of little economic importance.

Isles aux Morts Brook gold prospect (Cape Ray Fault):

The Isles aux Morts Brook gold prospect, in the southwest corner of the map area, has been the most recent subject of intensive mineral exploration and assessment (Northern Miner, 1977, 1978, 1980). Mineralization in the fault zone was discovered by George Bayly while prospecting for Brinex in 1968 (Northern Miner 1977). In 1975, part of the Brinex ground was optioned by Phillips Management, who engaged in a comprehensive exploration program. Amax aquired the property the following year, but released it after the summer assessment. The property was subsequently optioned by Riocanex, which launched a drilling program (Northern

Miner, 1977). In 1979, the company announced that a program of geological mapping, geochemical sampling, and geophysical surveying had indicated good potential for more deposits (Northern Miner, 1979).

The following description of the mineralization is taken mainly from the newspaper clippings (Northern Miner, 1977, 1979, 1980) and from Bucknell et al., (1980):

The Isles aux Morts Brook gold mineralization is concentrated largely in quartz veins, and is associated with base metal sulfides. The mineralized veins occur in two environments:

(1) Massive vein quartz is hosted by graphitic and chloritic schists of the Windsor Point Group (Emsian-Eifelian age), and mineralization occurs along a 2.5 mile strike length of the splay of the Cape Ray Fault system, which marks the southern fault contact of the group with the modified 'Bay du Nord' Group. The gold accompanies base metal sulfides. The quartz is fragmented, boudinaged, and locally incorporated in graphitic and chloritic fault gouge (D_3 regional deformation event). There may be local remobilization of the metallic minerals into the gouge.

(2) Networks of quartz veins follow fracture and joint sets in the Windowglass Hill Granite, a subvolcanic granophyre plug related to the Windsor Point Group felsic volcanic rocks. Variable gold values in the veins are associated with base metal sulfides, and pyrite is locally disseminated in the granite adjacent to the mineralized veins.

Significant factors relating to the mineralization may be: (1) the favorable precipitation environments offered by the locally graphitic Devonian rocks along the shear zone (Bucknell et al., 1980), (2) ophiolitic to island arc affinities of the Ordovician rocks traversed by the Devonian Cape Ray Fault system, and (3) Devonian hydrothermal activity associated with the fault system and the emplacement of the Windsor Point Group volcanic rocks along it.

It has been tentatively suggested that the ore-bearing fluids emanated from the Windowglass Hill Granite (Bucknell et al., 1980), a conclusion based partly on significant sodic enrichment of the Windowglass Hill Granite. The sodic enrichment takes the form of alteration of the granophyric feldspars to checkered albite. However, the soda metasomatism may be an effect of a more widespread hydrothermal system connected with the Cape Ray Fault and coeval structures in the vicinity of the granite, since checkered albite rims were also observed on feldspars in fractured phases of the southwestern perthite-rich leucogranite plutons (Unit 10). The development of chlorite-muscovite-quartz phyllonite from tonalite released calcium and sodium from hornblende and oligoclase during fault activity, and may have provided the abundant sodium necessary for hydrothermal albite formation.

Regionally widespread hydrothermal activity, possibly initiated during or prior to the earliest deformation in the area and subsequently localized along hydrothermal systems associated with the Cape Ray Fault system, may have been responsible for the removal of metallic elements from metamorphosed Ordovician crust. In a most favorable situation, metals could have previously been concentrated as massive or disseminated sulfides, rather than in trace quantities. Hydrothermal/metasomatic systems were active during polyphase deformation under amphibolite facies conditions throughout much of the terrane's development, and thus low water/rock ratios could induce enrichment in gold over base metals

relative to their original concentration ratio (Kerrich and Fryer, 1980). Likely pathways for the mineralizing fluids are blastomylonite zones, and ductile shear or slide zones (now silicified, and associated with D_2 and possibly D_3). Gold mineralization might result when:

(1) the solutions encountered chemical environments conducive to the precipitation of gold, such as local pockets of graphitic schist.

(2) fluid conditions, such as T, P(total), $P(H_2O)$, or $P(CO_2)$, are suddenly altered, decreasing metal solubilities, e.g. during tuffisite development in response to sudden boiling and degassing during regional uplift and pressure release along zones of weakness. Tuffisites are relatively common along mylonite or blastomylonite zones in general, and were observed locally in the mylonite at the northern contact of the Windsor Point Group in Isles aux Morts Brook, and also along Northwest Brook.

High CO_2 activity and carbonate alteration are commonly noted accompanying gold mineralization in shield areas. There are noteworthy abundances of carbonate in the sheared chloritic schists along the southern boundary of the Windsor Point Group, and as late calcite replacement around fracture zones in pre-Devonian rocks, and in calcite-hosted amphibolite breccias reported by Dingwell (1980) near the south coast.

8.4 Additional indications of mineralization

Additional metallic deposits encountered during this regional mapping program are the schistose, rusty rocks in the north-central high strain zone and a pyritized, silicic blastomylonite exposed in Grandys Brook.

The very schistose, rusty rocks occur where tonalite-intruded, high level gabbro and metadiabase (4a,1c) grades abruptly to tonalite-intruded, metasedimentary and mafic metavolcanic rocks (4b,2c,1d) in the 'metasomatic' part of the north-central high strain zone and along its western margin. Since the exposures are deeply weathered, representative 'fresh' samples are not available. However, samples from less weathered, adjacent exposures display silicification in the form of ubiquitous quartz overgrowths, locally profuse iron oxide minerals, replacement of plagioclase by muscovite and/or fibrolite, and leaching of biotite to a colorless mineral plus rutile.

Pyritized, silicic blastomylonite exposed on Grandys Brook is largely composed of flazer quartz with conspicous muscovite buttons along its foliation. The pyrite is disseminated as minute lenses. A similar, pyrite-bearing, silicified blastomylonite has been reported within the Cape Ray Fault zone along Nitty Gritty Brook in the La Poile River area (Chorlton, 1980b).

Two intrusive units, the quartz diorite - megacrystic granite (Unit 7) and the fine grained leucogranite (Unit 9), may also be associated with mineralization. The quartz diorite - megacrystic granite pluton was emplaced between the north-central high strain zone and the Cape Ray Fault zone, both with extensive hydrothermal-metasomatic systems for which the pluton could have provided heat for convection. A more extensive porphyry-type alteration system may be reflected by the late magmatic potassium silicate alteration characteristic of the pluton (i.e. orthoclase development and muscovitization of plagioclase). The fine grained granite (9), which occurs as an intrusion zone along Northwest Brook and as small lenses hosted by the foliated granitoid rock elsewhere (Figure 5), is associated with carbonaceous and hematitic alteration which suggests a potential for uranium or gold transport and mineralization.

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APPENDIX I:

PAST AND PRESENT LITHOSTRATIGRAPHIC CORRELATION IN SOUTHWEST NEWFOUNDLAND AS IT AFFECTS THE INTERPRETATION OF THE GRANDYS LAKE AREA

Cooper (1954) was first to define regional map units in the La Poile-Cinq Cerf map area to the east and southeast of the Grandys Lake area. Chorlton (1978a, 1978b, 1979, 1980a, 1980b) has since modified several units. Brown (1972, 1975, 1976a, 1976b, 1977) defined most of the lithostratigraphic units in the adjacent Port aux Basques (110/11) and Rose Blanche (110/10) areas to the southwest and south. New data gathered during the present mapping project indicates that several changes should be made to the previously accepted lithostratigraphic nomenclature and regional correlations for the purpose of describing the regional geology of the present area. The table of formations (Table 1) summarizes the previous and present terminology.

The previously proposed relationships are first reviewed, then revised if necessary. The originally proposed names of affected units will be used as subheadings below. The solutions utilized here are parenthisized with the subheadings for casual reference.

Long Range Gneiss, Northern Granite, and Long Range Mafic-Ultramafic Complex (Long Range Mafic-Ultramafic Complex cut by an unnamed tonalite)

The Long Range Gneiss (Brown, 1972, 1975, 1977) was defined as a tonalite gneiss with inclusions or pods of amphibolite and paragneiss, and was interpreted as Precambrian (Grenvillian) in age. Amphibolites apparently form the oldest rocks of the complex; they are coarse to fine grained, and locally display coarse gneissic banding. Relationships between the amphibolite and the paragneiss are uncertain, but Brown (1976b, 1977) interpreted both to have undergone the same early deformation and metamorphism before the intrusion of the tonalite and further deformation.

The Northern Granite (Cooper, 1954) is a deformed, largely tonalitic, granitoid intrusion which contains xenoliths of amphibolite, paragneiss, and local calc-silicate rock (Chorlton, 1980b). Chorlton (1980b) suggested that the Northern Granite and its inclusions might be related to the Long Range Gneiss of Brown (1977).

The Long Range Mafic-Ultramafic Complex (Brown, 1976b, 1977) was defined as a sequence of layered gabbros including overlying massive gabbro and underlying altered ultramafic rocks. According to Phair (1949), these rocks are part of a stratiform complex which is overlain by a roof zone of metasedimentary gneisses (part of the Long Range Gneiss). According to Brown (1976b), however, the complex is exposed as two thrust sheets which overlie the Long Range Gneiss. The lower sheet consists of tectonic pods of highly serpentinized dunite passing upward through actinolite-zoisite schist which grades into a locally thick sequence of amphibolite with remnant igneous banding. The upper sheet varies from feldspathic dunite at its base to a well layered series of troctolite, olivine gabbro, norite, and anorthosite capped by massive coarse and fine grained gabbro.

In the Grandys Lake area, foliated tonalite intrudes a segment of massive metagabbro and metadiabase identical to the rocks described by Brown (1976b) at the top of the upper sheet of the Long Range Mafic-Ultramafic Complex. West of the intruded segment, massive metagabbro and metadiabase grades into well layered troctolite, olivine gabbro, anorthositic gabbro, and anorthosite with granulite facies fabrics. The terrane consisting of massive metagabbro and metadiabase intruded by tonalite is characterized by large outcrop areas with only minor tonalite gradational into outcrop areas

where metagabbro and metadiabase forms xenoliths in tonalite. The tonalite with mafic meta-igneous inclusions passes northward into tonalite with assorted metasedimentary and mafic meta-igneous inclusions. It is suggested here that the Long Range Mafic-Ultramafic Complex therefore constitutes the oldest part of the Long Range Gneiss of Brown, and the intrusive tonalite the youngest part.

The intrusive tonalite can be considered correlative with the Northern Granite of Cooper (1954), but since the term granite is misleading this name is no longer applied and the intrusive tonalite is left unnamed. The name Long Range Gneiss is also dropped; however, the name Long Range Mafic-Ultramafic Complex is retained.

The existence of the thrust sheets reported by Brown (1976b, 1977) is supported by this study. However, the thrust contacts do not separate the Long Range Mafic-Ultramafic Complex from unrelated Grenvillian continental basement as formerly hypothesized, but occur between segments of the Long Range Mafic-Ultramafic Complex and its metasedimentary cover rocks, both intruded by tonalitic magma during thrusting.

Cape Ray Complex, Cape Ray Granite, and Red Rocks Granite (the name Cape Ray Complex and Cape Ray Granite are not used here, pending further investigation)

The Cape Ray Complex was originally defined by Brown (1972) as a tonalite gneiss complex, the former Long Range Gneiss (see above), cut by later granite bodies, the Cape Ray and Red Rocks Granites. The Cape Ray Granite was described as a megacrystic, pervasively deformed granite exposed at Cape Ray on the southwest coast. The name Red Rocks Granite was applied to a locally sheared, but largely unfoliated equigranular granite exposed at Red Rocks. The name Cape Ray Granite was later used by Brown (1977) to refer to a granite/quartz monzonite that varies from medium or coarse grained and equigranular to coarse grained and megacrystic in character. The equigranular granite at Red Rocks was then included in this unit, a correlation supported by Wilton (1981). The Cape Ray Granite as mapped by Brown (1977) apparently also includes a demonstably younger, perthite-rich, biotite leucogranite (Unit 10 of this report) exposed at the southwest corner of the Grandys Lake map area. Although the Cape Ray Granite as originally defined by Brown (1972) may possibly be correlated with a band of highly deformed, largely megacrystic quartz monzonite (6) which cuts the tonalite (4) and mafic meta-igneous rocks (1) in the southwest part of the Grandys Lake area (Chorlton and Dingwell, 1981), the name is not used here pending further investigation.

Port aux Basques Gneiss, Bay du Nord Group, and Harbour le Cou Group (continuous sequences informally designated here as Bay du Nord Group, a temporarily retained name)

The Harbour le Cou Group and the Bay du Nord Group have been interpreted as younger than the Port aux Basques Gneiss (Brown,1975,1976a). The Bay du Nord Group was originally assigned a Devonian age on the basis of plant fossils which were found in sedimentary rocks exposed in Billiards Brook along the northeastward extension of the Cape Ray Fault (Dorf and Cooper, 1943; Cooper, 1954). Brown (1975) considered it unlikely that Devonian rocks could have become as structurally and metamorphically complex as the Port aux Basques Gneiss, and accordingly suggested that the Bay du Nord Group was a cover sequence to the Port aux Basques Gneiss. The Harbour le Cou Group (Brown, 1975) shared recognizable primary sedimentary features with the Bay du Nord Group in the Rose Blanche area (110/10), and was considered its high grade equivalent. The Harbour le

Cou Group is exposed as two tectonic slivers faulted between slivers of the Port aux Basques Gneiss in a series of slide zones near the community of Rose Blanche. Microstructural reworking of the Port aux Basques Gneiss eastward from the community of Isle aux Morts toward these slide zones, with the resultant destruction of the evidence for a 'pre-slide' tectonic history, was invoked to explain why the Port aux Basques Gneiss could not be separated from the cover rocks in the field on the basis of tectonic fabrics (Brown, 1975, 1976a).

During subsequent mapping in the La Poile River area (110/16), it was discovered that the belt of Devonian fossiliferous sedimentary and associated volcanic rocks within the Cape Ray Fault zone are actually younger than the main part of the Bay du Nord Group as exposed near its type area of North Bay (Chorlton, 1978a, 1978b, 1980b). The fossiliferous rocks, informally named the Billiards Brook formation, were correlated with the Windsor Point Group to the southwest (Chorlton, 1980b). The remaining part of the Bay du Nord Group and the Harbour le Cou Group are considered pre-Devonian. Volcanic and subvolcanic rocks now included in the modified Bay du Nord Group (Chorlton, 1980b) in the La Poile Bay area have recently been dated radiometrically as middle or late Ordovician (Dallmeyer, 1979, 1981). In addition, the metamorphic and structural history of the modified Bay du Nord Group in the La Poile River area (Chorlton, 1980b) is the same as that proposed for the Port aux Basques Gneiss (Brown, 1975, 1976a, 1977). It is therefore suggested that the Port aux Basques Gneiss, the Harbour le Cou Group, and the modified Bay du Nord Group are equivalent.

The names Port aux Basques Gneiss and Harbour le Cou Group are dropped. The name Bay du Nord Group is temporarily retained to provide continuity with recent publications on the La Poile, Peter Snout West, and La Poile River areas (Chorlton, 1978, 1980a, 1980b), and further modified to include the former Port aux Basques Gneiss and Harbour le Cou Groups. However, it has become obvious that the substantial revisions to the boundaries of the former Bay du Nord Group necessitate renaming and redefinition of the group.

Rose Blanche Granite and Port aux Basques Granite (They are not clearly separable, and are probably emplaced at equivalent tectonic stages. The Rose Blanche and the Port aux Basques *phases* are referred to when necessary)

The Rose Blanche Granite (Brown, 1975, 1976a) has been defined and mapped in the Rose Blanche area (110/10) as a medium grained, equigranular granite to granodiorite which cuts the former 'reworked' Port aux Basques Gneiss, Harbour le Cou Group, and Bay du Nord Group prior to the 'reworking' deformation. Brown (1972, 1975, 1977) used the name Port aux Basques Granite for a foliated, pink to white weathering, equigranular granite which cuts his 'Port aux Basques Gneiss' as sheets early in tectonic history. Special reference was made to poikilitic blue-green hornblende and to feldspar augen, both of which occur locally in this granite.

The Rose Blanche Granite of Brown (1975) continues from its type area into the southeast half of the Grandys Lake area. It grades westward from massive, highly foliated granitoid with abundant screens of the modified 'Bay du Nord Group' through gneissic granite with abundant gneissic screens to numerous gneissic, sheet-like intrusions. Sheets within 5 km of the Cape Ray Fault locally contain poikilitic blue-green hornblende in the southwest part of the map area. This phase can be correlated with the Port aux Basques Granite of Brown (1975), which was mapped in the adjacent area to the south and southwest (Brown, 1976a, 1977).

Since the host rocks to the Port aux Basques Granite of Brown (the former Port aux Basques Gneiss) are no longer considered much older than the modified 'Bay du Nord Group,' there is no longer reason to infer that the early synkinematic granitoid rocks are different in age. Since they are mutually gradational, they are both included in the same general map unit (Unit 5 of this report).

Subtle differences between the former Rose Blanche Granite and the former Port aux Basques Granite as defined by Brown (1975) may be related to factors such as the tectonic position during and after emplacement, and related metasomatic activity, rather than independent genesis. Thus the terms Port aux Basques and Rose Blanche phases are used in order to provide direct comparisons with features described elsewhere (Brown, 1972, 1975, 1976a, 1977; Dingwell, 1980).

Windsor Point Group and Billiards Brook formation (They are equivalent. The Windsor Point Group is the name used)

The name Billiards Brook formation (Chorlton, 1978a, 1980b) was informally applied to a sequence of Devonian fossil bearing sedimentary and volcanic rocks exposed within the Cape Ray Fault in the La Poile River (110/16) area. A correlation with the Windsor Point Group (Brown, 1972, 1975) was suggested. This was confirmed on lithological grounds and on field relations while mapping the Grandys Lake area. Therefore, the name Windsor Point Group is now used for both the volcanic and sedimentary rocks of the group as originally defined and named Billiards Brook formation. The plant fossils (*Drepanophycus gaspianus*, *Taeniocrada*, *Psilophyton* sp., *Trimerophyton* (tentative), *Pertica*), originally found by Cooper (1954) in sedimentary strata along Billiards Brook and by N.R. Jayasinghe southwest of King George IV Lake (Kean and Jayasinghe, 1981), give the group an Emsian or Eifelian (late Early Devonian or early Middle Devonian) age (W.R. Forbes, personal communication, 1980, 1981). This has been confirmed from spores taken from the latter locality (D.C. McGregor, personal communication, 1981).

PART II: CARBONIFEROUS SEDIMENTARY ROCKS OF THE CODROY VALLEY

I. Knight

ABSTRACT

The Carboniferous sedimentary rocks consist largely of red and gray sandstone, siltstone, conglomerate with minor shale and limestone. They belong to the Anguille Group, the Codroy Group, and the Barachois Group, of which the Codroy Group is most extensively exposed in the map area. Alluvial fan and alluvial plain deposits, with minor lacustrine interbeds predominate.

The Codroy and Barachois Groups, of Viséan and Westphalian age, were deposited after emplacement of the youngest plutonic rocks in the terrane southeast of the Long Range Fault, but are deformed by the movement on the fault.

The Barachois Group hosts a small coal prospect.

1. INTRODUCTION

Carboniferous sedimentary rocks of Mississippian to Pennsylvanian age outcrop in the northwest corner of the Grandys Lake area, bounded on the southeast by the Long Range Fault. The Anguille, Codroy, and Barachois Groups occur in the map area, the Codroy Group being the most extensive. The succession is dissected by several faults and is generally poorly exposed, and some of the units are extrapolated into the map area from the adjoining St. Fintan's - Dashwoods area (12B/2-12B/1; Knight and Fong, 1976) and Codroy area (110/14; Knight and Brown, 1977).

2. STRATIGRAPHY

2.1 Anguille Group (Unit 12)

This group, exposed outside the map area, is largely composed of gray and red sandstone, black and gray shale, and minor conglomerate of Late Devonian to Early Mississippian (probable Tournaisian) age (Cote, 1964; Baird and Cote, 1964; Hacquebard, 1972; Knight, 1983). The topmost strata of this group, belonging to the Spout Falls Formation (Knight, 1983), are extrapolated into the northwestern part of the map area from the adjoining St. Fintan's area (12B/2). They probably consist of dark gray to black, well bedded, fine quartzose sandstone and siltstone, interpreted to occupy a small fault-bounded anticline. On the St. Fintan's map sheet, the strata of the Spout Fall Formation consist dominantly of red and gray sandstone.

2.2 Codroy Group (Units 13-16)

The Middle to Upper Viséan Codroy Group is characterized by fine to coarse, red and gray siliciclastic rock with minor gypsum, marine and caliche limestone (Knight, 1983). The group occupies most of the Codroy Valley in this map area, where it is represented by the Ship Cove (extrapolated), Codroy Road (extrapolated), and Robinsons River Formations.

Ship Cove Formation (Unit 13):

The Ship Cove Formation in adjoining map areas consists of well laminated, gray to black, bituminous limestone which upwards becomes more argillaceous and enriched in gypsum molds. The limestone apparently lies conformably on the Anguille sandstones in the neighbouring map areas. It is extrapolated from the St. Fintan's area (12B/2) to appear in the core of a fault-bounded

anticline. Details of the unit and its contacts are discussed elsewhere (Mamet, 1970; Geldsetzer, 1978; Knight and Fong, 1976; Knight, 1983).

Codroy Road Formation (Unit 14):

The Codroy Road Formation consists of gypsum, red and gray siltstone and mudstone, and black dolomite. This unit is extrapolated from the St. Fintan's area (12B/2) where it overlies the Ship Cove Formation (13) (Knight and Fong, 1976). It is postulated to be separated from younger Codroy Group units by northwest trending faults.

Robinsons River Formation (Units 15-16):

The Robinsons River Formation is characterized by terrigenous clastic rocks with lesser carbonate and evaporite strata, deposited within subzones B to D of the Windsor Group of Nova Scotia (Knight, 1983). It is the most extensive formation of Carboniferous rocks in the map area, and is subdivided into the Jeffrey's Village Member (15), exposed in the northwest corner of the area along the North Branch River, and the Mollichignick Member (16), which underlies the area northeast of the northwestern margin of the Long Range Fault. The Mollichignick Member is juxtaposed against the Jeffrey's Village Member by a northeast trending fault.

Jeffrey's Village Member (Unit 15)

This is the older member of the formation, and is better represented at its type section in the St. Georges Bay lowlands (Knight, 1983). The rocks exposed in this map area are similar to the upper half of the type section, and consist largely of fine siliciclastic rocks (15a) which include red and gray siltstone and mudstone with local thin, green and red, fine to very fine grained micaceous sandstone. Sedimentary structures in the sandstone include parallel lamination and ripple cross-lamination. The siltstone is mostly structureless, but fine lamination, mudcracks, plant rootlets, and caliche nodules occur locally.

Buff weathering, fossiliferous, sandy dolomite up to 5 m thick, is unevenly bedded, bioturbated, and rich in oncolites and fossils, including the mollusc *Aviculopecten*, the bryozoan *Batostomella*, abundant crinoid stems and ossicles, and plant trash. The dolomites are capped by a 70 cm thick concretionary and massive calcrete unit (15b). It occurs near Dingwells Pond, at the southern end of the carbonate unit, where it consists of a nodular and pisolitic upper layer underlain by more massive, slightly rubbly carbonate. It is overlain by red siltstone which has infiltrated and filled fractures and cavities in the calcrete. Other carbonate units (15c) are minor. They include 15 to 45 cm thick beds of black, lumpy, algal dolomite and dark gray, bioturbated, fossiliferous, argillaceous, dolomitic limestone. The fossils in this unit are typical of subzone B macrofaunas of the Windsor Group (Moore and Ryan, 1976).

Mollichignick Member (Unit 16)

Lithology: The Mollichignick Member is calculated to be about 2,200 m thick, and generally coarsens upwards toward the Long Range Fault. The lower half (16a) consists of gray and red, medium to very fine grained sandstone interbedded with red siltstone and some caliche limestone (16c). The upper half (16b) consists predominantly of brown red conglomerate and pebbly sandstone. These coarse siliciclastics are intercalated with sandstone, siltstone, and caliche limestone (16c) that resemble the finer beds of Unit 16a.

The lower sandstones (16a), characteristically rich in mica, are for the most part well cemented. Beds begin with sharp, planar bases that are generally overlain by thin planar stratification and lamination; locally they are capped by ripple drift.

Sandstone passes upward either gradationally or sharply into weakly fissile, red siltstone that contains mudcracks, caliche nodules, and local plant rootlets.

The upper part of the Mollichignick Member (16b) is dominated by brown red, and locally gray, pebbly sandstones and conglomerates, which are thickly bedded and crudely stratified. Pebbly sandstones display crude planar stratification and subordinate crossbedding. Thin beds and lenses of brown-red siltstone occur with the coarse grained strata. Pebbly sandstone and conglomerate form a continuous succession north of the South Branch River, east of the Trans Canada Highway, and close to the Long Range Fault. Traced southwestward into the subbasin, the pebbly sandstones and conglomerates thin to three distinct conglomeratic tongues, 1-30 m thick, that are intercalated with sandstone and siltstone facies (16a).

Gray caliche limestone (16c) is interbedded in the middle and upper parts of the Mollichignick Member. Where the succession is dominated by pebbly bands, 16c is associated with siltstone and intercalated rudite. Limestone interbeds are 30 to 130 cm thick, and contain massive, concretionary pisolitic and laminar structure with red siltstone partings and local stylolites. Cylindroids (Hubert et al., 1978) project down into the red siltstone beneath some beds.

The Mollichignick Member belongs to the upper part of the Codroy Group, and in the Codroy map area (110/14) includes thin marine bands containing Windsor subzone D/E macrofauna.

Petrography: Sandstones of the lower part of the Mollichignick Member (16a) are micaceous, lithic arkoses and subarkoses composed of 'common' quartz, polycrystalline metamorphic and plutonic quartz, feldspars, and micas mixed with schistose metamorphic and granitic lithic fragments. They are generally richer in micas, better sorted, and contain less mud matrix relative to those of the upper member (16b). Mica content may reach 50 per cent, and green biotite predominates in many of the rocks sectioned.

The conglomerates consist of angular pebbles and local cobbles of rock types similar to those of the adjacent metamorphic and intrusive rocks southeast of the Long Range Fault (e.g. Units 1, 2a, 4c,d, 8, 10). A typical suite of pebbles includes white vein quartz, red granite, white muscovite granite, red rhyolite, porphyritic rhyolite, granitic gneiss, green chlorite schist and phyllite, muscovite-biotite schist, quartz-muscovite schist, quartz mylonite, green gabbro, green-gray diabase, and local black chert.

Sandstones of the conglomerate sequence are lithic subarkoses and arkoses composed of quartz, polygonized and/or polycrystalline strained quartz, feldspars, and micas mixed with schistose and granitic lithic fragments. Significant, but rare, sillimanite-muscovite schist fragments occur with the other metamorphic clasts. The detrital heavy mineral suite is characterized by garnet and zoisite with subordinate epidote in addition to magnetite, zircon, and tourmaline (schorl). Micas include plentiful muscovite, green biotite, and both platy and felted chlorite. Brown biotite occurs rarely. Feldspars include both hematite-stained and sericitized orthoclase, fresh microcline, perthite, and partly altered plagioclase. The sandstones are characteristically matrix-rich, poorly sorted, and contain some carbonate cement. Heavy hematite impregnation and staining of matrix and micas are common.

2.3 Barachois Group (Unit 17)

The Barachois Group includes gray, locally pebbly arkosic sandstone, gray shale, and claystone, and several thin

coal beds, exposed in a narrow, fault-bounded wedge immediately adjacent to the Long Range Fault on Coal Brook. The unit is dated as Westphalian A by microspores from the coal beds (Hacquebard et al., 1961), and is thus equivalent in age to the Riversdale Group in Nova Scotia (Hacquebard, 1972).

3. DEPOSITIONAL ENVIRONMENT

Except for the Robinsons River Formation, the Carboniferous units are too poorly exposed and minor in distribution here to warrant detailed paleogeographic interpretation. A synopsis of the depositional environment of the Robinsons River Formation, with brief reference to the other units, is summarized from Knight (1983).

Carboniferous rocks of the map area were deposited close to the southeastern margin of an actively subsiding basin known as the Bay St. George subbasin (Knight, 1983). The Bay St. George subbasin is the northeast projection of the much larger Maritimes Basin of Williams (1973), a large successor basin filled with Carboniferous, predominantly molasse-type sediments. The southeast margin of the subbasin may have corresponded essentially with the Long Range Fault. A semiarid to arid climate is postulated for the subbasin throughout the depositional interval of the Anguille and Codroy Groups.

The youngest rocks of the Spout Falls Formation (Anguille Group) were deposited in a marginal, shallow lacustrine setting within a transitional zone that lay between red, sandy, braided fluviatile rocks to the northeast and gray, lacustrine-deltaic sedimentary rocks to the southwest. The subbasin was inundated by a widespead marine transgression at the beginning of the deposition of the Codroy Group, at which time a subtidal to intertidal, strandline carbonate (Ship Cove Formation) was deposited. This was superseded by alluvial and shallow marine sedimentation. Fine, gray, siliciclastic rocks, sulphate evaporites, and carbonates (Codroy Road Formation) were deposited at times of shallow marine flooding, and red siltstone and sandstone were laid down by shallow ephemeral streams on an alluvial plain. Similar alternation of fluvial sedimentation with minor shallow marine flooding occurred during the deposition of the Jeffrey's Village Member.

A distinct change of depositional environment occurred during the deposition of the Mollichignick Member (Robinsons River Formation), when sandy and gravelly, fluviatile sediments accumulated in alluvial fans. The brown-red, pebbly sandstones and conglomerates (16b) with thick, crude bedding and stratification were interpreted by Knight (1983) as waterlain, proximal alluvial deposits, probably generated by sheetwash and ephemeral flash floods (Bull, 1972). These pass to the northwest and basinward into thick units of micaceous, planar bedded and laminated sandstones overlain by red, crudely laminated siltstones. The latter are likewise interpreted by Knight (1983) as deposits of sheetwash shallow, ephemeral sandy streams generated by flash floods (Williams, 1971; Picard and High, 1973; Frostick and Reid, 1977; Tunbridge, 1981). The fine sand- and silt-size sediment (16a), reworked from fan slopes (Blissenbach, 1954; Hooke, 1967) or carried by stream floods was deposited on the lower fan slopes and on the alluvial plain fringing the fan (Bull, 1972; Hardie et al., 1978). Alluvial fans (Bull, 1972) and ephemeral stream deposits (Tunbridge, 1981), iron pigmentation in the sandstones (Walker, 1963, 1967a,b; Glennie, 1970), and thick caliche deposits (Gile et al., 1966; Reeves, 1970) indicate a semiarid climate at the time.

The caliche limestones (16c) resemble old pedogenic carbonate horizons (Reeves, 1970). Their presence

and stratigraphic distribution suggests prolonged intervals (over ten thousand years) of non-sedimentation on or at the toe of an alluvial fan (Leeder, 1975). This may have occurred during the abandonment of an active fan lobe as stream channels shifted on the fan, or alternatively as a result of recession of source or decrease in precipitation, so that sediment influx decreased, and the fan, in consequence, shrank in size.

The sandstone composition of the Mollichignick Member fan deposits (16b) suggests that the detrital source lay in the southern Long Range Mountains directly opposite the fan(s) in what is now the central and southern part of the Grandys Lake area. This is supported by the abundance of detrital garnet and zoisite, and the occurrence of sillimanite-bearing schists in addition to the other metamorphic and granitic rock fragments and mineral components. Rock types matching these clasts occur in the Stag Hill high strain zone of the Long Range upland terrane that lies directly southeast of the main Mollichignick fan deposit. Southwest of the map area, a different source is indicated by a contrasting mineral suite for younger Codroy Group fan deposits (Overfall Brook Member) (Knight, 1983). Arkoses of this member are composed dominantly of fresh granitic material, and lack the garnet and zoisite which characterize the Mollichignick Member. Analyses of grain size and sedimentary structures in the fan deposits of the Overfall Brook Member led Knight (1983) to suggest that the Overfall Brook Member was rooted against granitoid rocks within the Long Range upland terrane, probably along a fault scarp 5 to 10 km southeast of the present Long Range Fault. It is therefore tentatively suggested that no significant lateral displacements have occurred along the Long Range Fault since the late stages of Codroy Group deposition (Middle to Upper Visean time).

The Barachois Group, the youngest sequence, was deposited in the coal-forming, backswamp areas of a floodplain crossed by braided or meandering rivers.

4. STRUCTURAL DEVELOPMENT

Regional tectonism of Carboniferous strata of the Bay St. George subbasin is Westphalian or post Pennsylvanian in age. The deformation produced simple to complex, northeasterly trending folds and northeasterly and northwesterly trending faults. These structures are interpreted to reflect right lateral strike-slip movements on the Long Range Fault, and other faults that lie within the subbasin (Knight, 1983).

Within the Grandys Lake area, bedding, major faults, and fold axes of the Carboniferous sequence all trend northeastward, although a subordinate, northwest trending fault system also occurs. Bedding trends are locally variable near faults, and dips, generally low to moderate, steepen close to these structures. The Mollichignick Member occurs in a southeastward dipping, fault-bounded monoclinal block; bedding steepens towards the Long Range Fault where it is locally folded, with the southeast limbs of synclines commonly overturned.

The Long Range Fault is exposed at two locations along the South Branch River, where it is represented by a zone of brecciated sedimentary rock (16b) several metres wide juxtaposed against highly foliated amphibolite (1d) and pink granite (4d). There, the fault surface strikes approximately 055° and dips vertically to steeply southeast. On Coal Brook, the dip of the fault calculated from drill hole intersections was estimated to be 70° southeast by Hayes (1949), and vertical by Phair (1949) Minor fold axes within the Carboniferous rocks close to the Long Range Fault trend obliquely to the fault at 15° to

25° in a counterclockwise sense. Consequently, right lateral strike-slip movement has been postulated for the fault (Knight, 1983), although vertical displacement also occurred, resulting in upthrow of the Long Range upland terrane to the southeast relative to the Carboniferous sedimentary rocks (Hayes and Johnson, 1938; Mook, 1926; Knight, 1983).

Near the North Branch River, two northeast trending lineaments (air photo interpretation) mark the braided northeastward extension of the Ryans Hill Fault (Knight, 1983) from the Codroy area (110/14). Although the splays cannot be positioned exactly from the geology exposed, they juxtapose Anguille and lower Codroy Brook strata against the upper Codroy Group, and the fault zone is marked by local bedding discordance. The Mollichignick Member (upper Codroy Group) is downthrown at least 1,500 m against the Jeffrey's Village Member (lower Codroy Group) southeast of the main branch of the Ryans Hill Fault.

Northwest trending faults in the map area appear to dip consistently 65° to 75° northeast, and display limited vertical and horizontal movements. A major northwest trending fault on the St. Fintan's map sheet (12B/2) can be traced into the northern edge of this area, where it terminates against the Ryans Hill Fault. A downthrow to the southwest of about 500 m is likely.

No metamorphism accompanied the deformation of the Carboniferous sedimentary rocks away from the Long Range Fault. Chlorite, white mica, and extensive quartz veins occur within the Long Range Fault zone.

The geometry of the structures found within the Bay St. George subbasin corresponds to that expected for a right lateral wrench system (Wilcox et al., 1973). In the Grandys Lake area, trends of local fold axes oblique to the Long Range Fault are similar to those of major fold structures elsewhere in the subbasin. Nevertheless, there is no conclusive structural evidence for major strike-slip displacement, and the petrography of the Mollichignick Member alluvial fan deposits suggests little or no displacement of the fan from its detrital source southeast of the Long Range Fault.

Later vertical reactivation occurred along the northeast trending faults, with younger rock units downthrown, i.e., along the Ryans Hill Fault. Some fold trends and bedding attitudes in the Codroy area (110/14) also suggest later vertical movements along the Long Range Fault (Knight, 1983).

5. ECONOMIC GEOLOGY

The Carboniferous sedimentary rocks of the Bay St. George subbasin have potential for coal, uranium, gypsum, potash, and base metal mineralization. This area, however, is mainly recognized for its coal-bearing potential. Coal seams of Riversdalian age (Hacquebard et al., 1961; Utting 1966; Hacquebard, 1972) occur in a narrow, fault-bounded wedge of the Barachois Group which occurs close to the Long Range Fault on Coal Brook. The coal, first described by Howley (1897), occurs in a 75 m section with gray sandstone and interbedded shale and clay. The most important of the several coal seams and partings are the Jubilee seam (1.5 to 7 m thick; Howley, 1897) and the Begonia seam (60 cm thick; Hayes, 1949). The thick coal seams contain numerous shale partings, and are reportedly clean and pyrite-free. Minor workings were established by the Reid Company, from which a few hundred tons of coal (Hayes and Johnson, 1938) were retrieved; 95,000 to 195,000 tons are estimated for the area (MacLean, 1946). The seams are no longer exposed, and the mine structure is decayed.

Neither base metal nor uranium showings have been reported in the Carboniferous rocks of the Grandys Lake

area. However, base metal mineralization occurs near the base of the Codroy Group in the adjacent Codroy (110/14) and St. Fintan's (12B/2) areas (Knight and Brown, 1977; Knight and Fong, 1976). In the Codroy area, the Mollichignick Member contains minor uranium showings (Knight, 1983), and similar showings could be present in the Grandys Lake map area.

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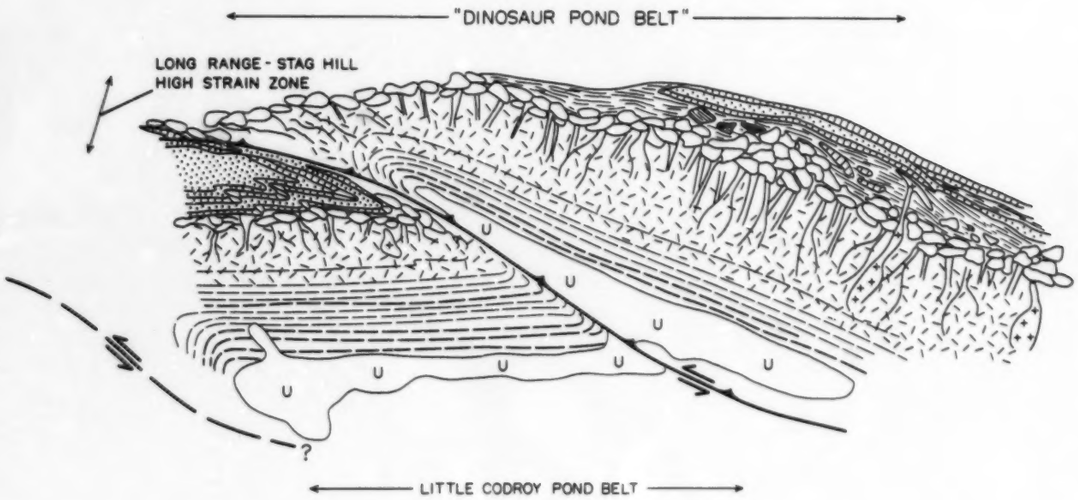
TABLE 1 : Table compares the rock units of three studies in or near the map area including the present study.

This Report				After Gillis (1972: Map Legend)				After Brown (1976a, 1977)			
PERIOD	**UNIT**	**LITHOLOGY**	**ERA**	**PERIOD**	**UNIT**	**LITHOLOGY**	**ERA**	**PERIOD**	**UNIT**	**LITHOLOGY**	**ERA**
Carboniferous		*Sedimentary rocks*		Devonian ?	Granitic rocks (includes: ISLES AUX MORTS BROOK GRANITE*, PETITES GRANITE**)	*Granites, many with unseparated inclusions of gneiss and schist: pink, equigranular to porphyritic granite and gray-tan quartz monzonite, granodiorite, pegmatite, pink granite*		Carboniferous ?	ISLES AUX MORTS BROOK GRANITE	*Pink, coarse grained, equigranular granite*	
Devonian or later?	Dikes	*Mafic dikes, plagioclase-quartz porphyritic rhyolite dikes*			*No contact*				*No contact*		
	Intrusive contact							Carboniferous or earlier	WINDSOR POINT GROUP	*Ignimbrite, rhyolite, shale, tuff, and conglomerate*	
	Perthite rich leucogranite	*Pink, medium to coarse grained, perthite rich leucogranite plutons, sparsely porphyritic rhyolite dikes*							*Cape Ray Fault unconformity*		
	No contact			Devonian or earlier ?	Granitic rocks (includes: ROSE BLANCHE GRANITE*, LA POILE BATHOLITH**)	*Granites, many with unseparated inclusions of gneiss and schist: gray to pink quartz monzonite and pegmatite; gray to pink, foliated, porphyritic quartz monzonite, granodiorite, minor pink granite and pegmatite*		Devonian or earlier ?	Cape Ray Fault zone	*Mylonitized gneiss and granite*	
Devonian	Fine grained leucogranite	*Fine grained, pink, subsolvus granite lenses and a larger intrusion zone, associated with intense alteration, carbonate patches*			*Intrusive contact*				*No contact*		
	No contact								LA POILE BATHOLITH	*Coarse grained, megacrystic, potassium feldspar-rich granite*	
	WINDSOR POINT GROUP	*Mafic and felsic volcanic rocks and sheared equivalents, volcaniclastic rocks, conglomerate, chlorite schist, carbonate-chlorite schist, siltstone*		Lower and/or Middle Devonian	BAY DU NORD GROUP	*Siltstone, argillite, sandstone, shale, slate, conglomerate, and metaconglomerate, minor phyllite, biotite-quartz-feldspar gneiss, and schist locally containing garnet, amphibole and staurolite*	PALEOZOIC		*No contact*		
	No contact				*Assumed contacts of unknown nature*				PETITES GRANITE	*Medium grained, equigranular, potassium feldspar-rich granite*	
Siluro-Devonian or earlier	Quartz diorite to megacrystic granite	*Quartz diorite; microcline porphyroblastic, mafic-rich granite; porphyritic quartz monzonite; aplite*		Ordovician(?) to Devonian	Mainly metamorphic rocks (includes: PORT AUX BASQUES GNEISS*, HARBOUR LE COU GROUP*, PARTS OF BAY DU NORD GROUP**)	*Biotite-quartz-feldspar gneiss and schist locally containing garnet, amphibole, sillimanite and kyanite; unseparated quartz monzonite, pegmatite, granodiorite, amphibolite, minor slate, siltstone, argillite, sandstone, tuff and metamorphic equivalents*			*Intrusive contact*		
	No contact				*Cape Ray Fault contact*				ROSE BLANCHE GRANITE	*Medium grained, equigranular garnetiferous, leucocratic granite to granodiorite*	PALEOZOIC
Silurian	(LA POILE BATHOLITH)	*Megacrystic quartz monzodiorite, aplite, pegmatite (not exposed here)*		Precambrian(?) to Ordovician(?)	Plutonic and metamorphic rocks	*Gabbro, diorite, granite, biotite-quartz-feldspar gneiss and schist locally containing garnet and amphibole, minor granodiorite, amphibolite, anorthosite, peridotite, dunite, marble, granodiorite, quartz diorite, quartz monzonite, monzonite, granite, gabbro, gneiss*	PRECAMBRIAN ?		*Intrusive contact*		
	Intrusive contact				*Approximate and assumed contacts of unknown nature*				BAY DU NORD GROUP	*Predominantly slate and phyllite with interbedded sandstone, grit and conglomerate*	
	ROSE BLANCHE AND PORT AUX BASQUES SYNMETAMORPHIC GRANITOID ROCKS	*Foliated, equigranular tonalite, granodiorite, minor granite, foliated granite to tonalite, pegmatite*			Mainly metamorphic rocks	*Biotite-quartz-feldspar gneiss and schist locally containing amphibole and garnet; unseparated granitic rocks, minor amphibolite and marble*			*No contact, possibly equivalent*		
	Cape Ray Fault contact								HARBOUR LE COU GROUP	*Pelitic to semipelitic schists with garnet and local sillimanite*	
Ordovician	Synkinematic granitoid rocks	*Foliated, equigranular biotite tonalite, garnetiferous tonalite, granodiorite and granite*							*No contact*		
	Cape Ray Fault contact								LONG RANGE MAFIC-ULTRAMAFIC COMPLEX	*Layered sequence of norites, troctolites and gabbros, overlain by massive gabbro and underlain by dunite, harzburgite and lherzolite*	
	MODIFIED 'BAY DU NORD GROUP'	*Semipelitic to pelitic schist and gneiss, garnet-staurolite-kyanite schist, migmatite, amphibolite, gedrite-bearing amphibolite and schist*							*Thrust contact*		
	No contact								CAPE RAY GRANITE	*Pink, mafic-poor equigranular to megacrystic quartz monzonite; coarse grained mafic-poor, potassium feldspar-rich granite*	
	Metasedimentary rocks	*Semipelitic, garnetiferous schist and gneiss, migmatite, marble, calc-silicate rocks, siliceous schist, psammite, metamorphosed clay and chert*							*Intrusive contact*		
Ordovician or Cambrian	LONG RANGE MAFIC-ULTRAMAFIC COMPLEX	*Layered, cumulate metagabbros and minor ultramafic rocks; massive, coarse to medium grained metagabbro, metadiabase and plagiogranite; derivative amphibolite*	PALEOZOIC						LONG RANGE GNEISS	*Tonalite gneiss with inclusions of earlier amphibolite and gneiss*	
									Cape Ray Fault		
									PORT AUX BASQUES GRANITE	*Pink, equigranular, potassium feldspar-rich granite*	
									PORT AUX BASQUES GNEISS	*Well banded, leucocratic and melanocratic gneiss with garnet, staurolite, kyanite and sillimanite; in part migmatitic*	PRECAMBRIAN

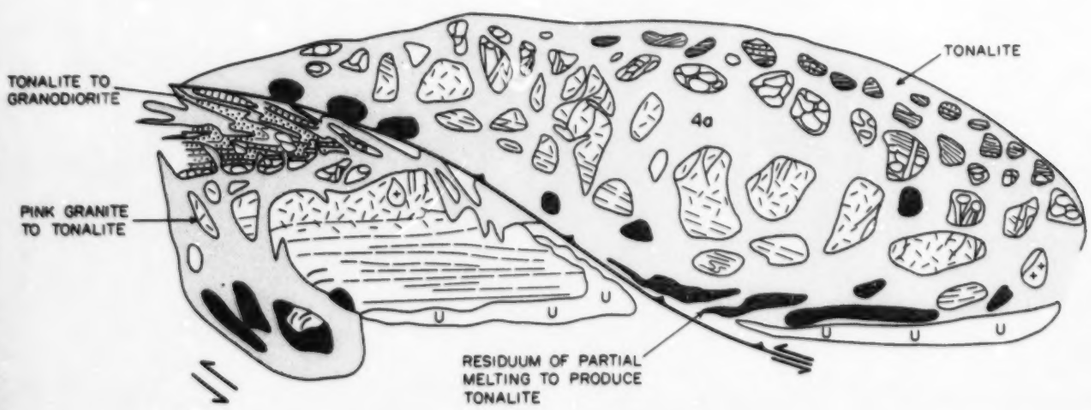
* Names used by Brown (1976a) but not by Gillis (1972)

** Names used by Cooper (1954) but not by Gillis (1972)

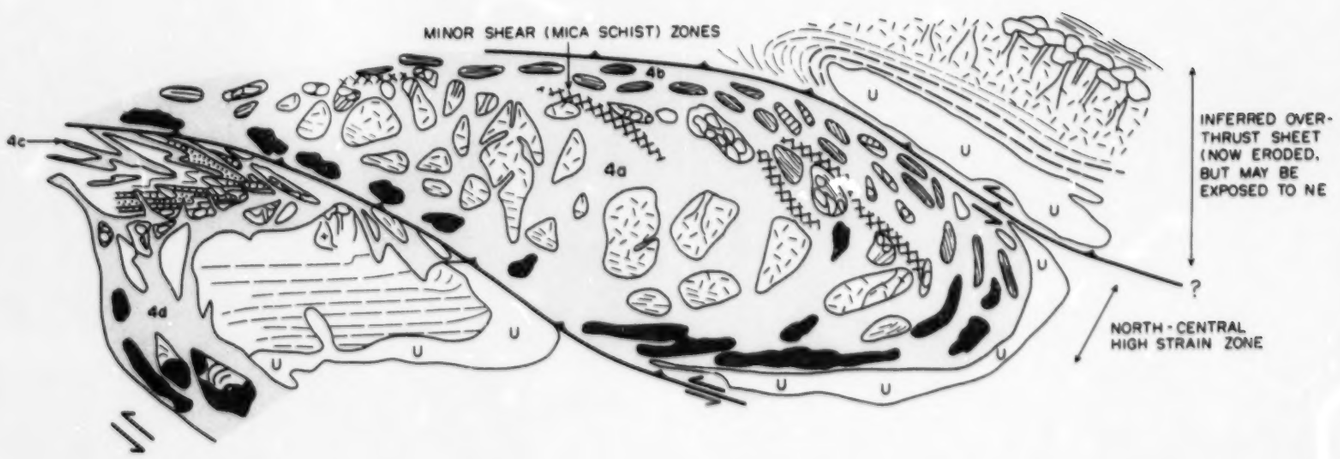
Figure 9: *Tentative Early Ordovician development of the ophiolite/tonalite terrane northwest of the Cape Ray Fault.*



a: *Initiation of ophiolite imbrication in terrane northwest of the Cape Ray Fault, Grandys Lake area. Note relative positions of the "Little Codroy Pond" and "Dinosaur Pond" belts, and the intervening Stag Hill high strain zone. (This activity may have occurred well below the surface).*



b: *Generation and emplacement of tonalite, granodiorite and minor granite. Tonalite (4a) is generated (from layered meta-gabbro?) near the sheared base of the "Dinosaur Pond belt," and lit-par-lit tonalite and granodiorite (4c) is generated in the metasedimentary and metavolcanic rocks underneath the thrust (in the Stag Hill and Long Range high strain zones). The granitic to tonalitic synkinematic granitoid rocks (4d) are generated still deeper in the mafic meta-igneous column intersected by another (postulated) high strain zone.*



c: *The "Dinosaur Pond belt" is overridden by yet another (postulated) thrust unit, and is highly deformed and metamorphosed in the north-central high strain zone.*

LEGEND

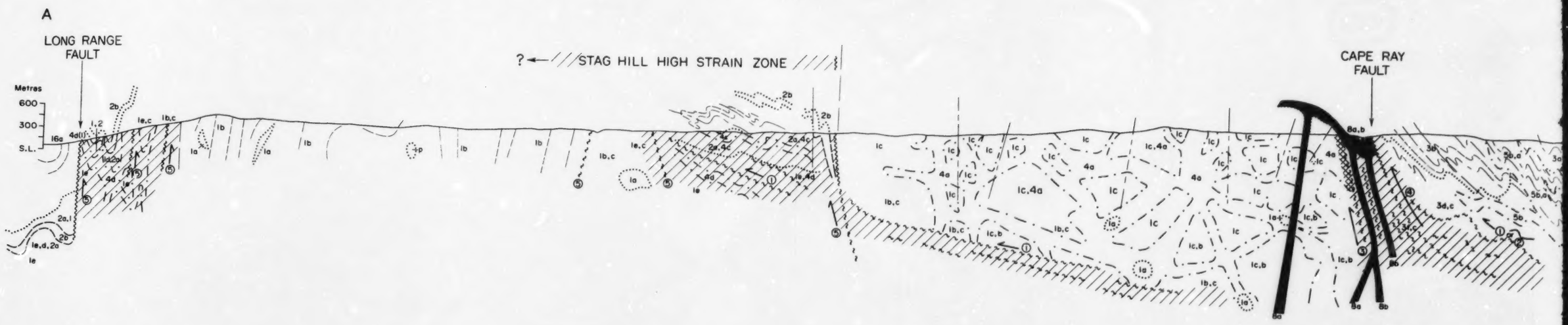
- *Limestone and shale or greywacke*
- *Mafic volcanic rocks and dykes*
- *Plagiogranite pods*
- *High level gabbro*
- *Layered cumulate olivine gabbro, troctolite, anorthosite, feldspathic peridotite*
- *Ultramafic rocks such as dunite, harzburgite*
- *Residuum of partial melting to produce synkinematic granitoid rocks*
- *Synkinematic granitoid rocks*

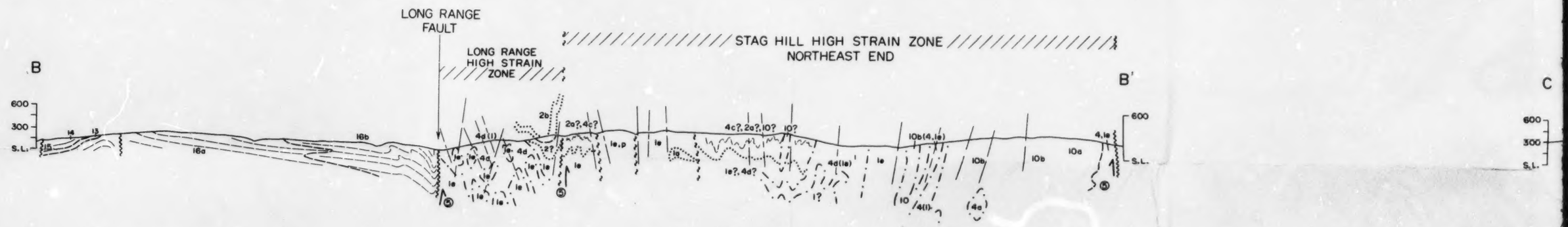
TABLE 4: Synopsis of emplacement and deposition, structural events and metamorphism.

Age	LITTLE CODROY POND BELT			DINOSAUR POND BELT			'BAY DU NORD ZONE'		
	Unit Emplaced or Deposited	Structural Events	Metamorphism	Unit Emplaced or Deposited	Structural Events	Metamorphism	Unit Emplaced or Deposited	Structural Events	
Carboniferous?		small scale faulting or fracturing			small scale faulting or fracturing			small scale faulting or fracturing,- warping, chevron folds, kinks	
	late dikes (11a, b)			late dikes (11a, b, c)			late dikes (11d)	D_3 deformation episode ('Bay du Nord Zone'): uplift of deepened 'Bay du Nord Group' and granitoid rocks against Windsor Point Group via oblique high angle thrusting; strain-slip fabric and dragfolding of amphibolite facies fabrics pass into mylonite zones	
Late Devonian						local hydrothermal activity along fracture zones in southwest corner of area			
	perthite-rich leucogranite pluton (10) spans eastern margin of belt			perthite-rich leucogranite plutons (1c), one spans western margin, another intrudes Windsor Point Group in southwest		contact metamorphism of highly retrogressed western margin	fine grained, two-feldspar leucogranite (9)		
Middle Devonian				Windsor Point Group (8) along Cape Ray Fault Zone			Windsor Point Group (8) along Cape Ray Fault Zone		
Early Devonian		partial uplift due to general uplift of ophiolite-tonalite terrane	(partial retrogression along lineaments?)		initiation of Cape Ray Fault as a left-lateral wrench fault accompanied by uplift of Dinosaur Pond belt (and probably partial uplift of more deeply buried belt to west)	retrogression to middle greenschist facies		initiation of Cape Ray as a left-lateral wrench fault culminating from D_2 ductile deformation episode	
				Quartz diorite-megacrystic granite (7) * may precede (6) below				D_2 deformation episode ('Bay du Nord Zone'): prominent schistosity, linear fabrics, mesoscopic folds	
Silurian	megacrystic quartz monzonite (6) spans eastern margin of belt			megacrystic quartz monzonite (6) spans western margin			[megacrystic La Poile batholith east of Grandys Lake area]		
		continued thrusting?				local metasomatic activity in north-central shear zone	synkinematic granitoid rocks (5) generated in situ and slightly deeper in tectonic pile		
				* (7)?				D_3 deformation episode ('Bay du Nord Zone'): tectonic stacking due to westerly(?)-directed thrusting	
Middle Ordovician					ductile shearing in north-central high strain zone due to a (hot) overriding nappe or thrust unit; composite foliation, gneissosity, lineation, dragfolds in north-central high strain zone, weak penetrative fabric in most of massive metagabbro subdomain; local biotite-muscovite phyllonites and other shear zones in transition between subdomains	middle to upper amphibolite facies in north-central shear zone, grades down through local shear zones and muscovite-biotite phyllonites to upper greenschist or lower amphibolite facies in massive metagabbro subdomain	[last stages of arc-related volcanic activity in volcanosedimentary pile southeast of Grandys Lake area]		
	synkinematic granitoid rocks (4) generated both in situ (4c,d) and slightly deeper (4d)	composite foliation, gneissosity, migmatitic banding, dragfolds, lineation	middle to upper amphibolite facies, with locally higher grade high strain zones transitional into layered metagabbro block	tonalite (4a,b) engulfs massive metagabbro (1c) and overlying rocks (2c, 1d) from below	shear zone or thrust sited below sequence exposed in belt		modified 'Bay du Nord Group'		
		thrust imbrication sited in shear zone(s); local blastomylonite horizons, tectonic thinning sited above layered metagabbros (in near surface rocks)		pegmatites	instability, fracture zones				
Early Ordovician	pegmatites			plagiogranite pods		submarine weathering in near-surface environments			
	ophiolitic plutonic rocks (1b,c) overlain by mafic volcanic rocks (1d), graywacke (2a) and marble (2b)	ductile shearing sited in layered metagabbros (1b); foliation, lineation, crenulated foliation	granulite facies in layered metagabbro block	ophiolitic plutonic rocks (1c) overlain by mafic volcanic rocks (1d) and clay, chert, mud, calcareous sediments (2c)					

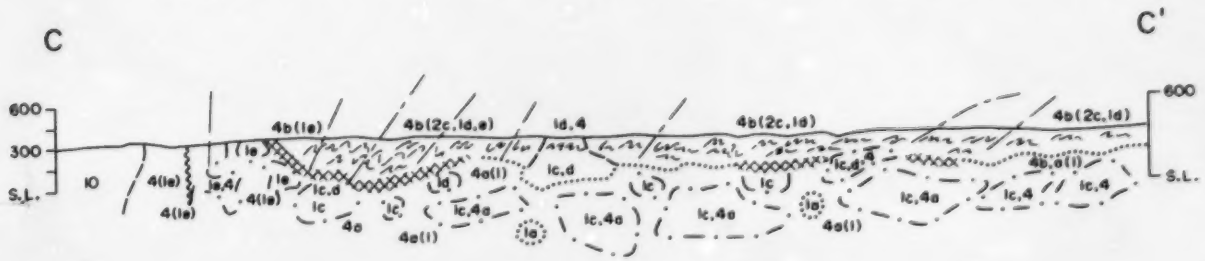
Metamorphism	'BAY DU NORD ZONE' Unit Emplaced or Deposited	Structural Events	Metamorphism	Age
		small scale faulting or fracturing, warping, chevron folds, kinks		Carboniferous?
	late dikes (11d)	D_3 deformation episode ('Bay du Nord Zone'): uplift of deepseated 'Bay du Nord Group' and granitoid rocks against Windsor Point Group via oblique high angle thrusting; strain-slip fabric and dragfolding of amphibolite facies fabrics pass into mylonite zones	greenschist facies in Windsor Point Group. 'Bay du Nord Group' finally retrogresses to greenschist facies along fault and related shear zones, but initiates deformation at amphibolite facies	Late Devonian
	fine grained, two-feldspar leucogranite (9)			
	Windsor Point Group (8) along Cape Ray Fault Zone		greenschist facies in Windsor Point Group. amphibolite facies in modified 'Bay du Nord Group'	Middle Devonian
		initiation of Cape Ray as a left-lateral wrench fault culminating from D_2 ductile deformation episode	(metasomatic-hydrothermal activity?)	Early Devonian
		D_2 deformation episode ('Bay du Nord Zone'): prominent schistosity, linear fabrics, mesoscopic folds	amphibolite facies	
	[megacrystic La Poile batholith east of Grandys Lake area]			
	synkinematic granitoid rocks (5) generated in situ and slightly deeper in tectonic pile		amphibolite facies attained after thrusting	Silurian
		D_1 deformation episode ('Bay du Nord Zone'): tectonic stacking due to westerly(?)-directed thrusting		
	[last stages of arc-related volcanic activity in volcanosedimentary pile southeast of Grandys Lake area]		greenschist facies	Middle Ordovician
	modified 'Bay du Nord Group'			
				Early Ordovician

INTERPRETIVE CROSS-SECTIONS



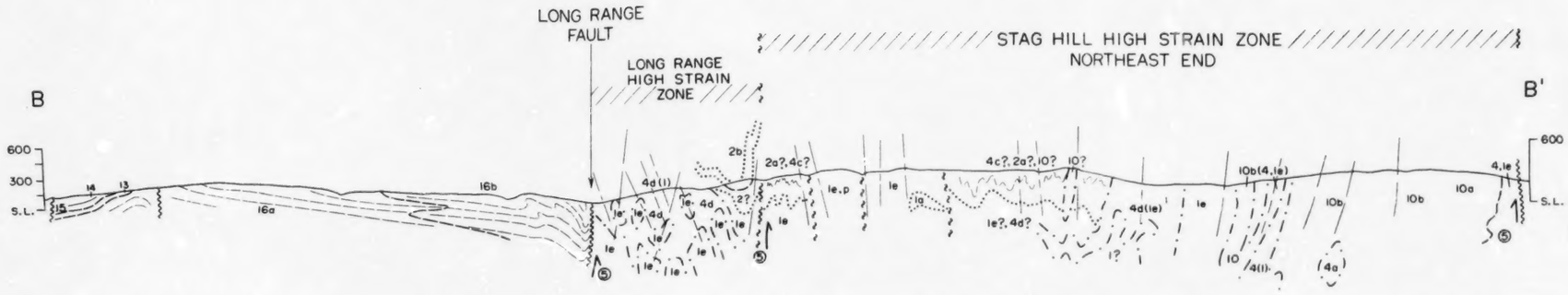


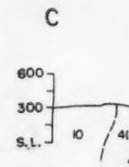
NORTH-CENTRAL HIGH STRAIN ZONE

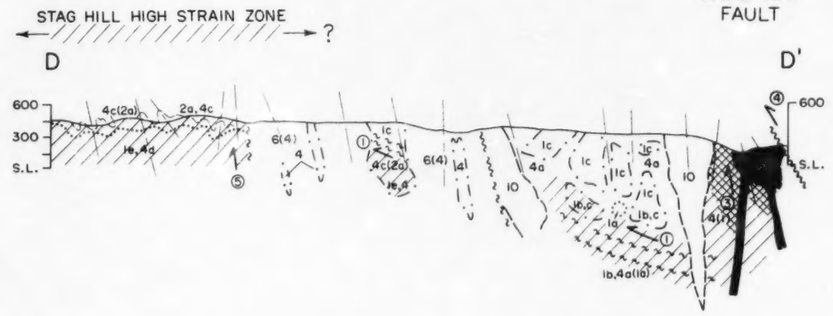


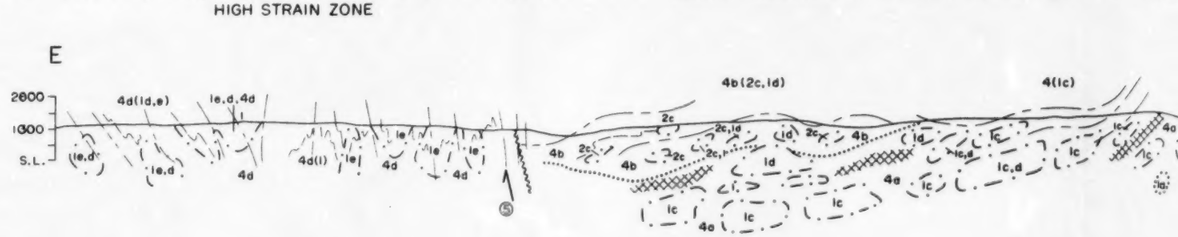
H STRAIN ZONE

CAPE RAY
FAULT









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- SYMBOLS -

Geological contact: approximate, assumed, gradational

S_0 or S_1: earliest recognizable fabric

S_2 schistosity, gneissosity

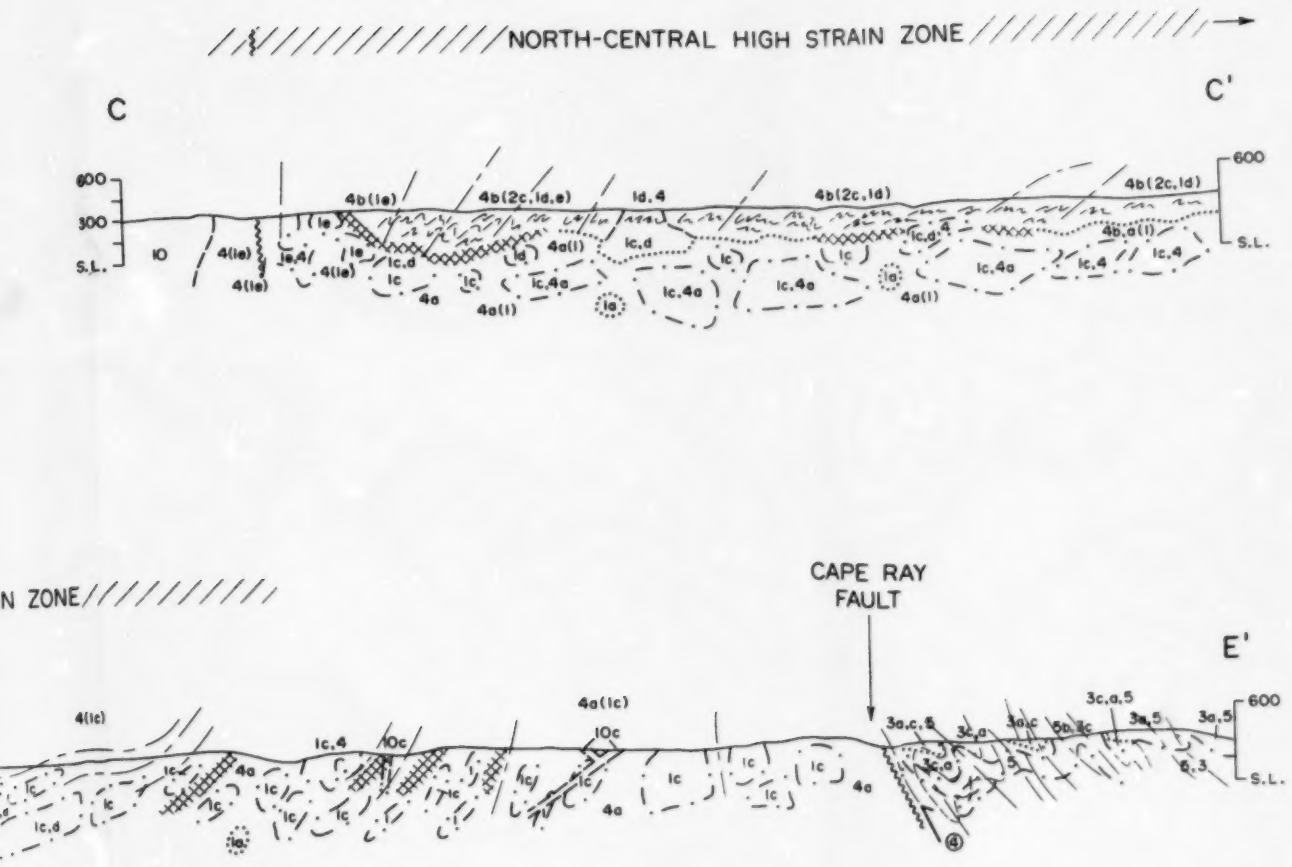
S_3 or late fracture, cleavage, ductile shear plane

Minor ductile shear zone, or phyllonite zone

Major high strain zone, thrust zone

Fault or mylonite zone: defined, approx., assumed

Fault: relative movement indicated by arrow; order of movement indicated by circled number



Cross Section to accompany Map 82 – 55 (Grandys Lake)

POOR

QUALITY

ORIGINAL